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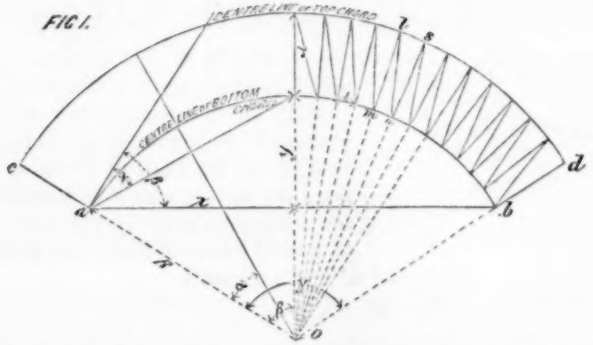
MAY, 1866.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Camber in Bridges. By ALFRED P. BOLLER, C.E.

The following investigation of the question of camber in bridges may be of interest and use to the younger members of the profession, and in that hope and spirit I submit it. In a horizontal truss, composed of top and bottom chords, diagonals, and verticals, the panels formed by the verticals are rectangular, the diagonals being simply the diagonals of rectangular figures. But where the beam is curved, or has a camber introduced, (which is measured by the versed sine of the curve at the centre of the chord line,) these verticals become the radii of a circle, of which the curved chords are arcs, and the diagonals are lengthened.



Take, as in the figure, an exaggerated case, letting $a\,b$ and $c\,d$ represent the arcs formed by the bottom and top chords, respectively,

and also let n equal the number of panels, d being their distance from centre to centre, measured along the centre line of the bottom chord.

Let γ = depth of truss, or rather, the distance between the centres of gravity of the top and bottom chords.

y and x = the camber and half span.

R = radius of the arc $a\,b$.

β, γ, θ = angles as marked on diagram.

n, d, x, and y are given, also $a\,b$ equal $n\,d$.

The trussed beam being built in a curve, the upper chord must, of course, be lengthened by an amount proportional to the radius of curvature, which produces a change in the panels, causing them to be longer along the top chord than along the bottom chord. The amount of this increased length is, of course, the same for every panel. The length of the top chord is represented by $\frac{\pi\,\rho\,v}{180} = 0{\cdot}0175\,(\text{R} + r)\,v$, in which $v = \gamma$. Therefore the total amount increase in the length of the top chord over the bottom chord is

$$0{\cdot}0175\,(\text{R} + r)\,v - n\,d = \delta, \quad . \quad . \quad . \quad (1.)$$

To find the radius of curvature, R, we have

$$\tan\,\alpha = \frac{y}{x};\ \beta = 2\,\alpha;\ \gamma = 4\,\alpha;\ \text{and}\ \theta = \frac{\gamma}{n}, \quad . \quad (2.)$$

$$\sin\,\beta = \frac{x}{\text{R}},\ \text{and}\ \text{R} = \frac{x}{\sin\,\beta}, \quad . \quad . \quad (3.)$$

Now, the number of panels being n, and the amount of *total* increase being δ, the lengthening for each panel along the top chord is—

$$\frac{n}{\delta} \quad . \quad . \quad . \quad . \quad (4.)$$

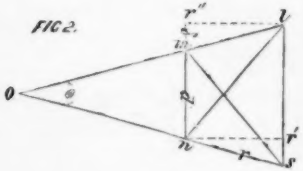
To find the length of the diagonals, let (Fig. 2) represent one panel, o being the centre of curvature. We have $r'\,n\,s = \frac{1}{2}\,\theta = r''\,l\,m$; $r''\ m = \frac{n}{2\,\delta}$, $\cos\,\frac{1}{2}\,\theta = \frac{l\,r''}{m\,l}$, and $l\,r'' = \cos\,\frac{1}{2}\,\theta \times m\,l$.

Then, from the right angled triangle $l\,r''\,n$, there results—

$$ln = \sqrt{r''\,l^2 + r''\,n^2}, \quad . \quad (5.)$$

which is the length of diagonal.

FIG 2.



Take as an example the camber in the proposed wrought iron International Bridge, to be built at Buffalo, over the Niagara River, which is intended to be six inches. r is 20·75 feet, the number of panels 24, and 10·7 feet, from centre to centre, along centre line of bottom chord.

$$a\,b = 10{\cdot}7 \times 24 = 256{\cdot}8.$$

$$\tan\,\alpha = \frac{y}{x} = \frac{{\cdot}50}{128} = {\cdot}003907 = 0° — 13' — 30''.$$

$\beta = 0° - 27'$; $\gamma = 0° - 54'$, and $\theta = 0° - 2' - 14''$.

$$\text{Sin } \beta = \frac{x}{R}, \text{ and } R = \frac{x}{\sin \beta} = \frac{128}{\sin 27'} = \frac{128}{\cdot 00785} = 16{,}305{\cdot}7 \text{ feet.}$$

Length of $c\,d$,

$$0{\cdot}0175\,(R + r)\,v = {\cdot}0175 \times 16{,}326{\cdot}4 \times \tfrac{9}{10}° = 257{\cdot}13,$$

$$c\,d - a\,b = 257{\cdot}13 - 256{\cdot}8 = 0{\cdot}33 \text{ feet} = 4 \text{ inches.}$$

The amount that each panel is to be lengthened along the top chord is $\frac{4}{24} = \frac{1}{6}$ of an inch.

For the lengths of the diagonals we have—

$r'\,n\,s = \frac{1}{2}\,\theta = 0° - 1' - 07''$; $m\,n = 10{\cdot}70$; $n\,s = 20{\cdot}75$.

$r''\,m = {\cdot}0075$; $\cos 0° - 1' - 07'' = \dfrac{l\,r}{m\,l}$, and $l\,r = 20{\cdot}75 \times 1 = 20{\cdot}75$ feet.

$l\,n = \sqrt{r''\,l^2 + r''\,n^2} = \sqrt{545{\cdot}21} = 23{\cdot}35$ feet.

The practice among many excellent bridge mechanics is to distribute equally the amount of camber among the panels along the top chord, which always increases the amount of camber. For example: Instead of distributing equally *four* inches among the panels, found in the above case to be required for a six-inch camber, they would distribute *six* inches, which would give nearly one-third more camber.

When camber is properly constructed in a bridge, the bottom chords are not strained by tension until the deflection of the truss is so great as to pass the horizontal chord-line. *Until* then the whole truss acts like a flat arch, and consequently, when the camber is considerable, no deduction for loss of strength by area cut away need be provided for, as would be necessary for a straight built beam, when deflection to the slightest amount would call upon the bottom chord to resist tension.

The graphical construction of the camber, in designing a bridge truss, may be very readily accomplished by starting from the *centre vertical*, working both ways to the abutments. First measure off the distance between centres of gravity of sections of the top and bottom

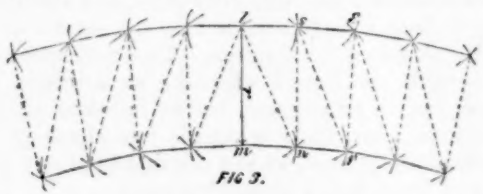


FIG 3.

chord along the centre vertical. Thus, in Fig. 3, $l\,m$ is the vertical at centre $= r$ in formula; $m\,n = d$; $l\,s = d + \dfrac{n}{\delta}$, and $l\,n$ is the calculated diagonal.

From the point m, with radius d, draw an arc, and with l as a centre, and the diagonal as the radius, cut this arc in n. With l as a centre, and $d + \frac{n}{\delta}$ as a radius, describe an arc, cutting it in s, using the diagonal as radius, with m as a centre. Repeat this same operation from the points n and s, to get the points e and f, and so on to the abutments. This method can be relied upon as simple, rapid, and accurate.

For the Journal of the Franklin Institute.

Sextant with Attached Spirit-level Horizon. By GEORGE DAVIDSON, Assistant U. S. Coast Survey.

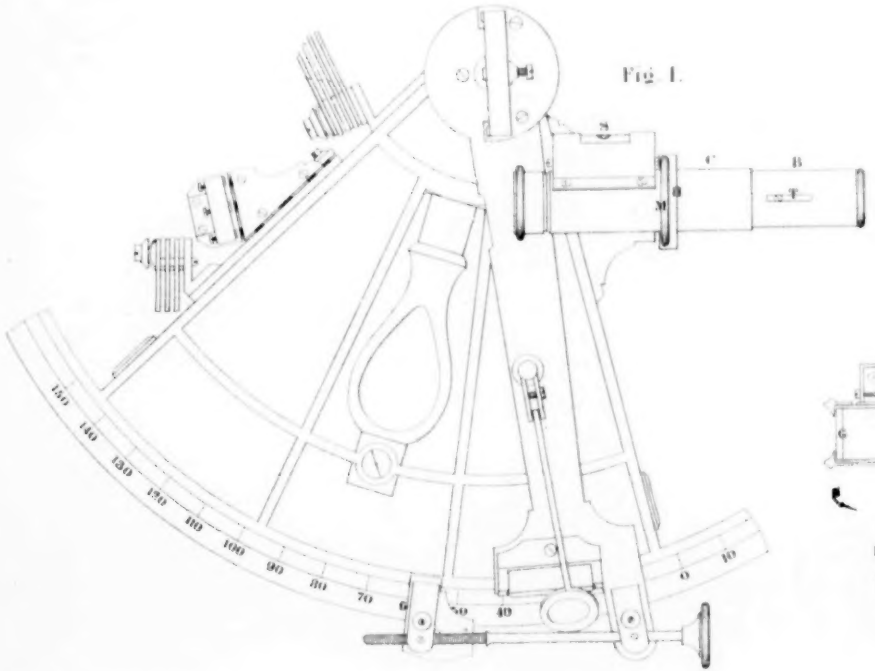
It very frequently happens that the traveler and the navigator are placed in situations where it is in the highest degree desirable to determine their geographical positions, or to measure the elevation of some mountain by an altitude or depression, and yet the means at their command may be inefficient. At sea, the sextant is the best available instrument for measuring angles of elevation or azimuth, but for the former purpose it can be used only when the object and sea horizon are both visible. Sometimes, however, when it is very desirable to measure an altitude, the sun is so low that the bright and dazzling reflection from the surface of the water obscures the horizon; or the horizon is hidden by a low fog whilst the sun is visible through it.

On shore, the traveler, whose outfit of astronomical instruments is limited to a pocket chronometer, sextant, and artificial horizon, finds constantly annoying occasions when his means fail him in important determinations. The sun may be too high for observing double reflections with the ordinary sextant; the sun or a mountain may be too low to admit of available reflection in the artificial horizon; and in particular these means positively fail him when, from any elevated point, he wishes to measure the depression of some object, as of the sea horizon, by which to determine his elevation or distance, knowing one of them, or, knowing the distance of another and lower mountain, to determine the difference of elevation.

We have encountered all these difficulties, and also the less frequent one of falling in with a reef at night with the stars visible but the sea horizon totally obscured in darkness. This occurrence first directed our attention to the subject of adjusting an artificial horizon to the sextant about twelve years since, but we failed to solve the problem. Three years since, when daily using the hand-level generally known to the trade as Locke's level, we saw the means at our hand ready for application, and fitted it to a Gambey sextant.

Plate IV. shows this level in detail. Fig. 1 gives the general appearance of the sextant and the attached level; Fig. 2 is a transverse section through the bubble, cross wire, and reflector; Fig. 3 is a longitudinal section through the bubble, reflector, and double convex lens. The tube B carrying the spirit-level is closed at each end with

Fig. I.



Sextant with Spirit Level Horizon.

by George Davidson.
Asst. U.S. Coast Survey.

Scale $\frac{1}{10}$

Fig. III.

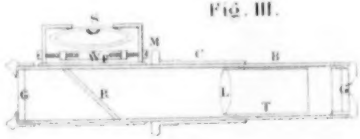


Fig. II.

plane glasses G G; the half of the tube lengthwise and on the side nearer the face of the sextant is unoccupied from end to end to permit vision directly through the plane glasses to any object or reflected object, whilst the other half carries the reflector R, having its reflecting surface towards the observer and placed at an angle of 45° with the axis of the tube, which also carries the half or segment of a double convex lens L secured in the inner tube T, which is capable of adjustment for difference of vision in different observers. Towards the object end of the tube B, over an opening above the reflector, is secured a small spirit-level S, with its axis parallel to the tube, and having, immediately beneath the tube, an adjustable frame F carrying a fine wire W at right angles to the axis of the tube and parallel to the horizontal plane. The images of the bubble of the spirit-level and of the cross wire are reflected through the lens to the eye of the observer. Other equivalent means may be employed for the above purposes, such as a prism for the reflector, &c.

For observations on land, where the instrument may be held with more steadiness than at sea, or even secured to a fixed object, a small telescope, such as the weakest power usually furnished with the sextant, may be fitted to the eye end of the tube, and thereby afford better results.

We have affixed the level to the sextant by having a tube C, about one inch in length, with a milled head M and exterior screw collar to screw into the telescope holder H of the instrument, and then sliding the tube B into it. This permits the use of the usual telescopes by removing the tube C.

The adjustment of this level is made either by changing the angle of the reflector, or moving the frame carrying the cross wire, or by elevating one end of the level itself; and consists in making the image of the cross-wire bisect the image of the bubble when a distant object in the same horizontal plane and seen through the unoccupied half of the tube appears on a level with the image of the cross-wire. This adjustment is readily effected on land, may be made by means of the level itself, and is not easily deranged. Should it, however, become necessary to adjust the level at sea, the image of the cross-wire, when it bisects the image of the bubble, is made to appear on the same line with the visible horizon; and the correction for the dip of the horizon at the given height of the observer's eye is applied to all observed altitudes and depressions.

The index error may be determined when the level is adjusted on land and used as a constant quantity for a not very extended series of observations, or it may be determined at sea whenever the horizon is visible, by observing the depression of the horizon and taking the difference or sum of the observed result and the computed dip for the index error.

The operation of making an observation for the altitude or depression of any object at sea or on land is as follows: Secure the level in its proper place on the instrument and hold the sextant in the usual manner, with the plane of its face in the vertical plane passing through

the object and the observer. Looking through the tube, move the vernier arm until the image of the object is seen through the unoccupied half of the tube, and bring that image into the same horizontal line with the image of the cross-wire at the time it bisects the image of the bubble, and if necessary note the time by chronometer. If the sextant and the level are in adjustment, the reading on the arc indicated by the vernier is the observed altitude or depression of the object.

At night, observations may be made by illuminating with a lamp or by chemical means. We have observed the altitude of the moon without any artificial light. Prof. Frazer suggests, as a chemical means of illumination, a small tube, containing phosphorus in oil, capable of being placed over the level at pleasure, and a small quantity of air admitted when the instrument is required for night observations. The length of the bubble of the unground level we experimented with was two-tenths of an inch, but should be shorter. The level had a radius of curvature of fifty-six inches, but for sea observations it may be smaller for bad weather and until practice be acquired.

The following results from observations for latitude are given as exhibiting what was done at the second and third trials with the instrument. It is believed that, with practice and a level adapted for the duty, much better results can be obtained, especially in the hands of a more experienced observer with the sextant.

Latitude from circummeridian altitudes of the sun with sextant and spirit-level horizon. Observations of November 11th commenced 5 min. 48 sec. before apparent noon, and ended 11 min. 18 sec. after noon. November 12th commenced 7 min. 23 sec. before, and ended 5 min. 55 sec. after apparent noon.

November 11, 1865.		November 12, 1865.	
⊙	⊙	⊙	⊙
39° 59′ 18″	39° 57′ 14″	39° 60′ 12″	39° 54′ 19″
55′ 55″	57′ 36″	59′ 28″	56′ 37″
57′ 05″	57′ 18″	57′ 51″	56′ 31″
56′ 52″	58′ 41″	57′ 39″	58′ 13″
57′ 55″	59′ 43″	56′ 01″	57′ 51″
55′ 52″	61′ 27″	56′ 59″	58′ 29″
58′ 41″	. . . . .	58′ 54″	59′ 01″
Means, 39° 57′ 23″	39° 58′ 38″	39° 58′ 09″	39° 57′ 17″

These reductions have been unnecessarily made to seconds of arc that the actual working of the instrument may be seen; the probable error of one observation deduced from these series is one minute of arc, and the probable error of the mean of all the observations is thirty-five seconds of arc. This, of course, excludes whatever constant errors may have existed.

The following observations were made for index error:

November 11, 1865. Off the Arc.		November 12, 1865. Off the Arc.	
+ 0′ 40″	+ 1′ 50″	+ 1′ 50″	+ 1′ 20″
3 20	2 20	4 20	1 20
3 20	3 40	2 20	2 50
4 00	3 10	4 30	1 30
2 30	1 10	1 50	3 30
3 40	2 10	2 50	1 50
Mean,	+ 2′ 39″	Mean,	+ 2′ 39″

And the probable error of one observation is three-quarters of a minute of arc.

Observations for error of chronometer have been made with the instrument, and it has been used to measure the difference of elevation of objects above and below the plane of the observer when it was impossible to get their reflection in the ordinary artificial horizon.

A thorough trial will be made of this improvement this season, when the results can be compared directly with the determinations of the Coast Survey.

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*Fire-proof Materials and Construction.** By T. Hayter Lewis, F. R. I. B. A.

From the London Civil Engineer and Architect's Journal. August, 1865.

In connexion with the use of iron, and of the metals generally, in building construction, it may be remarked that the softer ones, as lead and zinc, are, of course, fit only for covering, and do not enter much into the subject. But in thinking of them for roofing, we must remember that zinc melts at a low heat (700°) and then burns fiercely. Lead melts at a somewhat lower temperature, (594°.) Iron, however, is a great aid now in construction, and its almost universal use suggests the need of most careful research with respect to it. Now, undoubtedly, it is relied upon by the public as being a safeguard against fire. Undoubtedly, too, its use is looked upon by the insurance offices as being more dangerous than that of wood. Its first and most obvious defect is its rapidly deteriorating strength when heated, and though the fact is well known, it is curious that experiments vary very much indeed as to the measure of deterioration. All agree in the fact that at and above red heat, (which is common enough in fires,) the diminution in strength is great; but below that opinions differ much. Mr. Braidwood's opinion was that iron begins to lose its strength even at such low temperature as 100° and upwards. Mr. Hodgkinson thought that the strength was only slightly diminished at any temperature under 600°, (the melting point of cast iron being 2786°,) and was not very much so until red hot, and the experiments made by him and Mr. Fairbairn are by no means clear in their results. It is highly important that the exact facts should be ascertained, because, of course, a

* Excerpt Proceedings Royal Institute of British Architects. Session 1864-65.

low temperature is more common than a high one. My own opinion, from careful observation after every case of consequence, is that wrought iron is very sensibly weakened, and cast iron rendered brittle at comparatively low heats; because it is very common to find iron ties and other similar work bent merely by their own weight, in small buildings and other places where the heat has clearly, from other evidence, not been great. The failure of the wrought iron girders also, drawn from examples at a recent fire, shown on the drawings, tend to the same conclusion, for the whole of them were bent, twisted, or broken in the most violent way, although the cast iron columns on which they rested were only slightly bent. These columns were, however, of much stronger form than is usually found. Anyhow it is quite certain that at higher temperatures, such as are to be expected in a large fire, iron rapidly loses strength, and thus a floor or a beam which would bear the weight upon it quite safely at an ordinary temperature, might break down at a higher one. But I come now to consider of the greater heats constantly produced in our larger fires, and where iron and brass are actually melted. (Specimens of both taken from a recent fire were exhibited.) The temperature here must have been about 3000°, and the metals retained no strength whatever to sustain even their own weight. Now, there can be no doubt that iron offers us most admirable aid with our columns and girders, when used as metals should be; and now that we are getting out of the way of imitating stone-work in iron, and that we are using and ornamenting iron as a definite material, undisguised, it is likely to influence, and ought to influence most materially, our designs; and when we call to mind the extraordinary differences produced in its qualities, by such comparatively trifling differences in treatment as those which produce cast iron, wrought iron, and steel, annealed and case-hardened iron, we may not be without hope that means may be found of removing the defects which now militate so seriously against its use. Meanwhile we must look upon it as being a most dangerous ally.

Wood is not quite so dangerous a material as is supposed. For instance, I have seen some posts and a girder which remained to the end of the fire which melted the iron and brass within 10 or 12 feet of them. A piece of another post from the same building, and close to the same part of it, where the wood was burnt in to some little distance, and scorched deeply in, yet still retained its strength. Several others remained in the same state, and in ordinary fires large timbers are seldom burnt right through, but have enough of their substance left to act as struts or girders, though, of course, much weakened. Doubtless, in the case of such extreme heat as above, there is some current of air which carried the flames away from the wood; but none of the firemen present could say how.

I come next to *concrete*. This is much used for fire-proof floors, and likely to be for many other purposes, as bricks are now getting so very dear. We know well, from the examples of old walling, how valuable a material this is, as we have all seen it remaining quite sound after being used for the hearting of a wall, after its Roman or Me-

diæval casing has been destroyed for ages. But, so far as my present purpose is concerned, we must accept its use with some reservation. The whole question was entered into very fully by Mr. Tite and others at the Institute, in the discussion on Mr. Burnell's paper, and his opinion was that ordinary concrete was not to be trusted. Clearly flint-work is unsafe, as the flint is calcined so much by fire that walls made of them are shattered to pieces by it. So are the ordinary gravel pebbles, of which here are some specimens. But concrete may be made of broken bricks, as the old Romans made it, and as, I think, Mr. Tite has used it in several cases. I have a high opinion of concrete in fire-proofing, but there have been, nevertheless, cases of some suspicion as to the perfect protection to be derived from its use.

The last substance to which I shall allude in detail is ordinary plaster—perhaps the most valuable auxiliary that we have—as might be expected from its non-conducting properties, proved clearly in the very elaborate experiments made on this subject by Mr. Hutchinson. He tried most building materials carefully, and showed that a combination of lime, sand, plaster of paris, &c., had less conducting power than any of the others.

I must now consider the combination of these several materials in different forms of construction, and the subject will naturally come under the divisions of walls, piers, columns, or other detached supports, floors, stairs, and roofs. The walls are, of course, the most important, but the least difficult in execution, as brick is at once the best and most common material, for inside work at least. In fact it is, I think, an almost unexampled case for a fire to destroy an ordinary thick wall, as the flames naturally ascend, directing their force on the ceilings, through which they usually find vent; and I have seen fires of great strength stopped even by thin partitions. I saw one case, in the old town of Hamburgh, where a large warehouse was destroyed, but where the fire had not injured the adjoining warehouse, although separated from it by brick nogging only. Sometimes, however, there is such a stop to the flames from a stubborn ceiling or arch, as to allow them no decided vent, and then the walls are exposed to the full action of the fire. Yet even then I have never known good brick walls to fail by being burnt in. There was a great proof of their strength in the case of the vaults of the Tooley Street warehouses, many of which were filled with oil, converted by the flames into a rolling sea of fire, which burnt for weeks. These vaults were built in the usual way of good groined arches, supported on brick piers, and not an arch nor a pier broke down under the trial, nor, after a recent examination of those that still remain, could I see that even a joint had given way. But every portion of the stores over, many of which were built of iron girders on iron columns, presented such a scene of utter ruin that one could scarcely dream of. No one who had ever seen it would place faith again in iron. The greatest damage is to be feared in time of winter, and when the fire is over; then, if one side of a wall has been saturated with water, and the other not so, the water

in the open joints freezes, expands, lifts the brickwork on the one side, and bends the wall. I must qualify this opinion as to the sufficiency of brick walls, by saying that the brickwork must be well done; for I have seen cases in which the work was filled in so badly, that smoke poured through the wall at every joint; there was, of course, but little safety there. I, of course, suppose that all the walls are of a fair thickness, but it would lead to too long a controversy to discuss here as to what that thickness should be. I must also qualify what I have above said, with respect to walls of hollow or pierced brick. For various reasons I much doubt the effect of fire upon them, but I have not seen them tried practically, so that I speak upon this part of my subject with hesitation.

Next to the walls come the piers and columns, and these are clearly the most important parts of the building. Their construction is often easy enough on the basement, where space is not usually so much an object; but above that story, anything larger than a story post or iron columns is seldom allowed. I have already alluded to the defects of iron, and at present I know of no method of insuring safety in its use. Several means have been suggested. Mr. Hosking tried, in one very extensive warehouse, the plan of putting the columns double in two separate rings, one, in fact, enclosed within the other, his idea being that if one were to break or bend, the other would safely bear the weight. I certainly doubt this much, and in any case the expense is very great, and the size of the columns very much enlarged.

I myself once tried the somewhat contradictory plan of encasing the iron columns with a thick layer of plaster. There is no great difficulty in getting the plaster firmly to adhere, and I think that the plan would be a safer one than that of the double columns. But I am not over sanguine about it, and the system is, at least, liable to the artistic objection that it conceals the more valuable material of the two. I have already alluded to the plan of sending air through the columns, but there is another plan which has found favor with many, and which provides for filling the columns and girders with water. This, at first sight, seems plausible enough; but the least thought shows numerous objections. There is, first, the risk of the water freezing, and so bursting the iron—or of the latter expanding, and so letting the water leak at the joints. There must be risk of this, even with ordinary changes of temperature, subject, as the floors must be, to heavy pressure, and still more so in case of fire when every circumstance is intensified to an extraordinary degree. We must, too, then find the hollows either open to the cistern head or closed securely; if open, the intense heat will convert the water into steam, and blow it out; and if closed, the heat will convert the hollow spaces into so many boilers, charged with steam at a high pressure, without escape valves, and tear the whole to pieces.

But the whole question of supports is intimately connected with that of the floors which they carry. Now, I will first take the case of private houses, where there is usually nothing but the ordinary furniture to burn beyond the constructive part. I assume, of course,

that such precautions have been taken as to make the skirtings and partitions solid, because if drafts are allowed through and beyond these the fire will soon be led through them in spite of every effort. But such precautions having been taken, I see no great difficulty in protecting the house. You may do it as the French do, by iron joists, &c., or in the way used here, and known as Fox and Barrett's plan, or by any way by which the spaces between the iron may safely be filled in with good plaster or other concrete; and doubtless, with long bearings, iron must be used in some way, nor is its use objectionable where such low temperatures only are to be looked for, and when protected by a plastered ceiling. But, in addition to the cost of the iron, it is a material always troublesome to use: one wants to trim a floor, or bevil off a headway, and so on—things done easily enough in wood, but often very difficult or costly with iron; and I really do not see that it possesses any advantage over wood, when the latter is equally protected by plaster and concrete with the iron.

This protection may be had in several ways. We may adopt the ordinary French plan, as described by Mr. Hosking, viz: of having very strong laths, filling in the ceiling from above on to a temporary scaffolding, (instead of pressing it upwards, as with us,) and filling in the whole space between the joists with rubble, so as to form a solid flooring. But this plan has the disadvantage, that the whole weight of the ceiling is carried by the nails of the lathing, and any carelessness or want of skill (not unlikely to be experienced in the use of a method new to our workmen) may produce fatal results. With iron joists the laths rest on the flanges, and iron has thus so far an advantage over wood. But I feel quite satisfied that strong, thick pugging would be almost equally efficacious if the sound boards be split in narrow widths, and the soffits plastered so as to form one mass with the pugging over, thus leaving but a very small part of the bottom of the joists exposed. This would be still further protected by the key of the plaster ceiling, if the sound boarding could be brought so low as that the key of the plaster ceiling would unite with that of the pugging. The difficulty in the way is that the fillets must then be brought so low (close to the soffit of the joists) as to render the latter liable to be split and weakened by the fillet nails. An ingenious plan of obviating this was used by Mr. Marrable at the Board of Works offices in Spring-gardens, viz: cutting the joists in a wedge form, (two out of one, so as not to waste the timber,) so that the concrete filling-in used there had, when dry, all the properties of an arch, and pressed against the joists as its abutment, instead of bearing with its full weight upon the fillets. The floor over being tongued, the draft will be stopped, I fully believe, almost as well as by Hartley's plates. I have recently seen a case of a fire in a warehouse, where the heat was so severe that the wrought iron doors were bent so as to be useless, and yet the wooden-tongued floor had completely prevented the flames from spreading downwards.

Another way of forming floors has been much used in the Midland counties, and is well known as Dennett's, being formed of concrete,

to which I have already favorably alluded. The patentees claim for it greater lightness, solidity, and cheapness than four and a half inch brick arching, and I fully believe it has them. But the absence of lateral pressure is also claimed; and I cannot at all understand this. If the arch form be of any use, it can certainly only be, as far as I can see, by a pressure on the abutments. If the material itself give the strength, and the abutments are not strained, the floor may as well be laid flat. With good abutments there is much to recommend this plan, as it will, I think, be efficacious, and the arched form worked out of the actual solid, and not by plaster bracketing, (as dangerous in case of fire as false in construction,) is very much the thing we want, to help us to variety in the section of our ceilings. If, however, the bearings are of iron, Dennett's plan is open to all the objections to which the iron itself is liable. There are also in the South Kensington Museum a great many full-sized models of plans for fire-proof construction, but all, I think, without exception, depend upon iron girders for their bearings or abutments, or such a condition must be fatal to their use. Of another plan, suggested by Alderman Waterlow, where the strength of the floor depends upon the system of iron rods, built into, and therefore protected by, the concrete, I speak with reservation, as the system has never yet been tested by an actual fire. But in ordinary houses the heat is so comparatively slight, and the force of the flames so taken off generally by the stairs as an outlet, that there seems to be little difficulty in protecting the floor, whether by this or by other methods. It is in the construction of warehouses and other large places, wherein large masses of combustible matter are stored, that we meet with the really great difficulty, for we have to encounter there an excess of temperature unknown elsewhere. Of all the plans that have been tried for the protection of these places, I suppose that the one of brick arches carried by cast iron girders is that most commonly used. Doubtless such a floor would be of use in order to prevent fire spreading downwards. But the iron-lined ceilings as used at Nottingham and elsewhere, where the floors are inflammable, owing to the oil dropping from the machinery, or even an iron-tongued floor, where no such extra risk exists, would go far towards answering the same purpose, whilst what I have already said will show how little dependence can be placed upon the iron if the heat can only get at it. Even if the girders themselves could resist the heat and the water, the arches would at once be deprived of the tie which forms their security, by the bending of the tie rods. For I never remember to have seen a case in which rods, used for whatever purpose, were not found so bent after a fire as to show that their strength as ties are gone. It so happens, too, that the form of the iron girder, often adopted as being the strongest in section, viz: that of the reversed V, is really the weakest in case of fire, as the latter has free access to it in every part, whereas, the only chance of a girder being saved is the smallness of its section exposed to the fire.

The system of girders or joists filled in with plaster or concrete is much better than the last, as no tie is required, and, doubtless, in small

cases they may be useful. But I have seen them often tested in large fires, and I remember no instance in which they have there formed an effectual stop. (I am now, of course, speaking of warehouses, or such buildings, and not private houses.) I may again bring forward the wrought iron girders shown on the drawings as a case in point, for these formed portions of a floor which had been filled with concrete 18 inches thick. But the ceiling had been formed of boarding only, the soffits of the girders were exposed to the direct action of the fire, and the greater part of the building destroyed. There is, however, always a difficulty in these cases in determining whether the actual cause of the failure was the iron columns or the girders which they support; for if the columns fail, the bearings of the girders fail also, and the girders must bend or break with the heat and weight. In one remarkable case, where the columns had not been injured, the system had apparently succeeded, the fire having begun on an upper story, and failed at first to work down through the concrete floor. But, some hours after it was supposed to have been subdued, it burst out on the lower story, having apparently sent a stream of heated air through some crack in the concrete, and the whole building was then soon utterly wrecked. This building offered a curious instance in another way of the danger of iron construction. It was circular in plan, the girders radiating to the outer walls from a circular framing in the centre. The ironwork got heated, expanded, and so injured the walls that nearly the whole had to be rebuilt; whereas, I feel quite satisfied that all would have been saved had the girders been of wood. A curious instance of the danger of iron is given in the drawing of brick arches, being a section of part of a building very much injured by fire some years since. The fire broke out on the story covered with this arched construction assumed to be fire-proof. All the arches rested on cast iron girders, except the arch next to the wall, the girder adjoining which turned out to be of wood, put in either by accident, or perhaps as a piece of scamping work. It is the only case of the sort that I remember. The lower surface was exposed in precisely the same way and to precisely the same extent as that of each of the iron girders. The fire was one of the fiercest that I ever remember, and burnt into the brick of the wall, directly under the wood, to a depth of nearly an inch, that having been clearly the hottest part. Yet every iron girder broke in half, throwing down the iron arches which they bore, whilst the wooden one remained to the last, with no more injury than its being turned into charcoal for an inch or so in depth. But I must ask you to consider this question as to wood a little further.

If we examine how buildings built of wood give way, we shall find that, as a general rule, they are constructed with long girders of fir, supported on posts or columns, also of fir, connected together only by the thin joists which carry the deal flooring. These latter, unprotected by ceilings, and seldom even by tonguing, are burnt rapidly away, the heavy timbers, thus left without connexions to steady them, sway over with their weight, fall into the burning ruins, and add to

the fire. Now, if these heavy timbers and posts were of the hard wood which was used of old, and if the space between the joists were filled in solidly with such material as the pugging which Lord Stanhope used, we should have a flooring of much greater value in time of fire than any I know, short of real arches on real brick piers. I do not say that it will be depended upon to stop a fire if once it got ahead. Nothing but arches or piers will do that, unless you divide your warehouses with upright walls, so as to lessen the mass of fire; nor do I contend that there is not a great disadvantage in the use of timber, from its certainty to increase the body of fire if the stairs, for instance, fairly ignite, or the floors give way. But I *do* say, that the danger from the risk of sudden failure in the iron more than counterbalances this; and that if stairs, and floors, and columns were made as I have alluded to, they would offer such chances of delay as might be of the utmost use in preventing loss; and I know well that the men in the brigade would feel themselves secure with such construction, and fearlessly work to save it; whereas, even Captain Shaw himself would hesitate to lead, or the most daring of his men to follow him, into a building, when they know that the lives of all within it depended upon a frame of iron.

I must offer a few words as to *roofs*. The objections that I have elsewhere offered to the use of iron do not apply here, and it is probably the best material to be used. But I must venture to give a caution that battens must be used in the covering, and not boarding, as the fire runs along the latter with great rapidity. I must also notice another practical point recently brought under my notice by Captain Shaw, and which had quite escaped me, viz: that when cisterns are provided against the risk of fire, they should be at a considerable height, as it takes a pressure of 15 feet of water to open the firemen's hose.

I now come to the last part of my subject, and perhaps the most important of any, viz: the stairs. The example I have selected is one of melancholy interest, as it was connected with the deaths of three persons; but the construction of the staircase was of so uncommon a character, as to make it an unusually good case to which to refer. It had walls on three sides, but on the fourth only a thick quarter partition, not brick-nogged, but lathed and plastered as usual. The steps were of good sound Portland, with one end pinned well into the side of the wall, and secured into the wooden partition by strong cross-pieces of wood framed with the uprights. The landings were formed of wooden joists, with plaster ceilings. The fire broke out in the basement story, and could have been of no very great intensity, as the ceiling over was not at all burnt through, and all that there was to feed the fire was the kitchen floor, fittings, and one cross partition. It passed through the door on to the stairs, swept up the stairs, was stopped by a lath and plaster ceiling at top, and rushed out by a window close under it. All the doors of the various rooms leading on to the stairs were shut, so that no damage was done to any of the rooms except by smoke and water. Now, this is a good illustration of the

effect of the first sudden burst of flame, for there was nothing to burn or add to the fire on the staircase, and the only heat was from the rush of flame; yet, before any of the engines began to play, the staircase broke down from the top, and crashed down the whole underneath, leaving the ends projecting from the walls and wooden partitions, which latter held the stair-ends as firmly as the walls did. I was, at first, quite puzzled to account for this. At length I found that a large cistern was on the upper story, full charged at the time of the fire; that a hole had been burnt through the service-pipe from it, directly over the top steps, upon which, thereupon, the whole weight of cold water had come down suddenly, in their heated state. These had snapped off and broken the rest (rendered brittle by heat) in falling. I have since seen another stone staircase, of similar construction, broken down from apparently the same cause, and others would, of course, follow in the same way directly the engines played upon them. But the fact to which I wish to draw your attention more particularly is that the only parts of the whole staircase which remained secure were the wooden landings, protected only by the plaster ceilings; and that, while every part of the fire-proof construction was utterly destroyed, I took my observations in complete security on these said landings, which remained to the last uninjured.

As a practical result I may, however, say generally that, if the stairs be supported at each end, as they were in the old geometrical and other staircases, it matters very little what their construction may be, as they would be pretty safe any way. For you will find that the way in which a staircase of stone is destroyed, is by the fire rushing up the central well-hole and heating the outer ends to excess. The steps thus become excessively brittle, and snap off at once whenever any sudden weight or change of temperature is brought upon them. With wooden stairs the case is different; they are seldom set fire to from underneath, as the plaster ceilings invariably protect them, unless the plastering is very bad. But the outer string exposed to the full force of the flame catches fire; the flame spreads thence to the riser and the tread, gets thus *behind* the plastering, and the stairs are then destroyed. The present fashion of cut-string is a wonderful help to fire, as it gets at once, without a step, from the outer string to the treads and risers, and it would be no slight step towards safety if the present fashion were discarded in favor of the old massive solid strings and newels. If these were reused, and the stairs made solid with plaster, on some plan like the French, there can be no question whatever that wooden stairs would be something very nearly fire-proof. I ought to refer here to one fine example of a different construction—that of old Rochester castle—the old staircases whereof are formed of concrete, bedded on wooden templates, the marks of which remain now as perfect as the day on which they were laid; and I believe that these old stairs would resist now the trial of fire as they have that of time and weather for some five centuries.

Telemeters, or Instruments for Measuring Distances.

By the late ARCHIBALD H. BELL, M. A.

From the London Mechanics' Magazine, November, 1865.

It is surprising that, notwithstanding the great development during the last few years of the science of gunnery, and the perfection to which guns and projectiles have been brought, one of the most important problems connected with the subject has not as yet received the attention which it obviously deserves, and still awaits satisfactory solution. I allude to the problem of determining the distance of objects. To judge distances accurately and with rapidity has at all times been of very great importance to artillerymen; but since the introduction of rifled ordnance this importance has incalculably increased. We have now guns capable of doing fearful execution at a distance of two miles and a half (4400 yards)—guns capable of efficiently throwing projectiles to a greater range than that at which the Americans boast to have shelled the forts and city of Charleston. The promptitude and certainty with which bodies of men and ships of war are now moved add greatly to the importance of this subject. Powerful steamers, for bombardment or for transport, can be brought into action at the rate of fourteen knots an hour, and be withdrawn as rapidly—a pace far exceeding that of the best appointed four-in-hand coach, or a troop of horse artillery at full gallop. The distance of such a vessel from a battery might vary as much as 100 yards in fifteen seconds, or a quarter of a mile in little more than one minute. Of what avail, then, is the beautifully rifled gun, the accurately fitting projectile, the nicely fixed tangent scale with its verniers, if the true range cannot be determined correctly and instantaneously? What advantage is there in a good direction, rapidity of fire, and penetrating power, if the gun be laid on a point 100 yards or 200 yards beyond or short of the object aimed at? To draw increased attention to this subject is the aim of the following remarks: "*Utila deliberare, mora utilissima est,*" and if this end shall in any degree be attained, it is to be hoped that the service will at length obtain what at present it so urgently requires.

We want the power to determine distances up to two miles and a half with great rapidity, and with sufficient accuracy to enable us to strike such an object as a battalion in column, or a ship of war. By practice the eye may be trained to estimate distances under half a mile with fair precision. At Hythe, the principal school of musketry, this practice is made of prominent importance, and it is found that the average men of a well-drilled class do not err in judging distances of half a mile and under by more than one-tenth of the distance. But it may be asserted, absolutely, that no man can arrogate to himself the power of judging distances of a mile and upwards, with the very smallest degree of certainty; and we therefore require to seek for some kind of instrument for the purpose of obtaining this power. The difficulty to be contended with here is, that no definite space of time, not even one minute, can be allowed for adjusting an instrument, or for

calculation; and thence arises the danger that the most perfectly-contrived instrument may be imperfectly used in the hurry and excitement of action. The requirements of such an instrument for military use are, therefore, 1. That it shall be of simple construction; 2. That it shall be capable of being used with rapidity, and shall show the result at a glance; 3. That any error of adjustment shall be easily recognizable, and readily admit of rectification.

In order to make our professional wants as clear and simple as possible, I classify the various circumstances under which we have to estimate distances as follows: 1. Horse and field artillery require to ascertain the distances of objects over land, whatever may be the features and elevations of the ground, and frequently without much topographical knowledge of the surrounding country. 2. Garrison artillery also require to estimate distances over land, but with the advantage of a perfect acquaintance with the localities and landmarks. 3. We require likewise to estimate distances over water, from forts and batteries on the sea-shore, whether *a fleur d'eau*, or in elevated positions. 4. We require to estimate distances on board ship, where not only the object but also the observer may be in motion. With regard to these four cases, it may be remarked, that it is perhaps of the least relative importance for horse and field artillery to possess instruments for measuring distances. Our magnificent mounted artillery come so rapidly into action that one or two trial shots could probably be always fired before any satisfactory observation could be taken with an instrument; and the shot thus thrown away are not of the same value as the ponderous projectiles of modern garrison and naval artillery. Even in the case of garrison artillery, it may be argued that an instrument is not of vital importance, for the reason to which I alluded above, that, whether the battery be in our own fortifications (a battery of defence), or form part of a siege attack (a battery of offence), the ground in front is usually so studied and planned out that the ranges of all the remarkable objects in sight are well known, and little more information is required of the distance of any object, whether stationary or in motion.

But it must be allowed by every one that it is of the very highest importance that we should possess instruments to enable us to determine distances over the sea from shore batteries. The guns used here are usually of the heaviest nature, throwing the most costly projectiles, and requiring very large charges of gunpowder; they are of necessity slow to load and to manœuvre, and the objects fired at are oftentimes in rapid motion. Trial shots would here be of little use, as there remains nothing to guide the eye to the spot where the last shot struck. In these cases, too, time is everything; the tremendous blow must be struck at one particular moment, or the opportunity may never recur. Consider, for example, the forts at the mouth of a harbor, (at the passage of the Needles, or the much-discussed forts at Spithead,) if the very first round fail to crush a hostile vessel advancing at full speed, her escape is certain; and the battery, placed there solely for the purpose of stopping her, has been merely money thrown away.

The fourth requirement is one of the navy rather than of our own profession, but it is of equal public importance; and though there are many difficulties in this form of the problem, there is every reason to believe its solution to be quite practicable, and that it will some day be effected. It may be that a distinct form of instrument is required for each of these four cases, and for this reason I have kept them separate, as failure is often caused by an attempt to achieve a too comprehensive success. By considering each of these cases by itself and in detail, we may hope to hit upon some good means of attaining our particular object.

Among the most beautiful of the instruments hitherto produced for the purpose of measuring distances, may be mentioned the inventions of Cavallo, of Rochan, of Professor Piazzi Smyth, Astronomer Royal at Edinburgh, of Lieutenant-Colonel Clerk, of our own Regiment; and of M. Otto Struve, Astronomer Royal at St. Petersburg. None of these have yet been introduced into our service—"*Certant, et adhuc sub judice lis est.*" I should, however, mention that M. Otto Struve's instrument was some years ago introduced into the Russian service, and is now in use at Cronstadt. Without now entering into the details of these inventions, I may remark that there is one fundamental principle upon which they all depend, and upon which all our efforts to estimate distance must be built, viz: that knowing the base of an isosceles (or of a right-angled) triangle, we can ascertain the height by measuring the vertical angle. We unconsciously put this principle into practice at every moment of the day,—the distance between the pupils of our eyes being the base of the triangle, of which the sides are the rays of light passing from any point of the object looked at to our two eyes. The old experiment of trying to snuff a candle with one eye shut, shows us that we cannot appreciate distance with one eye with the precision and promptness we can attain with both eyes open. When using one eye only, we are instinctively forced to reverse the mode of applying the principle, and to take as our base some known or supposed dimension of the object, and to estimate the angle formed by the rays of light passing to the pupil of our one eye from the two extremities of this distant base. It is in this reversed or one-eyed manner that the instruments of Cavallo and Rochan are constructed; the actual size of some distant object, such as the height of a man, is assumed as known, and the distance is estimated by noting the number of graduations which the object subtends on a micrometer in the eye-piece of a telescope. Now, we might possibly obtain satisfactory results from these instruments, if the enemy's army could be forced to pass a night in our own bed of Procrustes; but as men vary in size by as much as *one-seventh* of their height, and as their apparent height varies considerably by the different national and regimental forms of head-gear, thickness of boots, and other circumstances, it can easily be conceived that the error with these instruments may be very great, probably as much as *one-tenth* of the whole distance, or 176 yards in one mile, quite enough to make artillery practice very harmless.

A method of estimating distances without any special instrument, by the assumed size of an object, (such as the average height of a man,) has been lately proposed by J. M. de Tilly, (Sous-lieutenant de l'Artillerie Belge,) an account of which may be found in the *Revue de Technologie Militaire*, tome iii. He proposes to have upon the chase of a gun, (see Fig. 1,) and near to the muzzle, a foresight a' b', capable of sliding backwards and forwards, parallel to the axis of the piece. The gun having been laid upon the bottom p of the object $p\,q$, while the foresight is in its position a b nearest to the breech, the foresight is moved towards the muzzle until its upper edge is just in line with the top of q of the object; the space a a', over which the foresight has

Fig. 1.

passed is noted, and the distance of the object calculated, or the distances may be graduated upon the chase of the gun. With reference to this method of estimating distances, we may observe that it has all the disadvantages of Cavallo and Rochan's micrometers, with the additional objection of impeding the proper use of a gun at the very time when probably it is most needed.

We may further remark that, practically, this means cannot be used for distances over 1200 metres, and that at that range the error may amount to as much as 89 metres. M. de Tilly also proposes a method of measuring distances by means of two guns and a measured base, (see Fig. 2.) The two guns, a f and b e, are placed about twenty yards apart, the wheels covering each other; the right-hand gun is then laid upon the object with 10° right deflection; the left-hand gun is laid upon the same object with 10° left deflection; the exact distance $a\,b$ between the tangent scales of the two guns is then measured with a tape or chain. Each gun is provided with a sliding foresight c and d similar to that above-mentioned; the tangent scale of each is also furnished with a horizontal arm $a\,o$ and $b\,o$ perpendicular to the axis of the gun. The foresights c and d are now moved until they are in the prolongation of these horizontal arms of the alternate guns, and the distances from the tangent scales to the foresights are

FIG 2

measured, or they may be graduated upon the guns. From these data, viz: 1st, the distance apart of the guns; 2d, the angle of deflection at which they are laid; 3d, the distances from the tangent scales to the sliding foresights—the distance of the object may be calculated, or a set of tables may be previously calculated of the distances corresponding to all possible value of the variables. The material required to carry this theory into practice are, then—1st, two guns, with special arms to the tangent scales, and a movable foresight to each; 2d, a measuring tape or chain; 3d, a set of intricate tabulated calculations; and, lastly, four men to take the observations and measure the base. With all this, the errors which may arise in such observations are three-fold: 1, a possible error in the positions of the foresights; 2, in the measurement from gun to gun; and 3, in the laying of the guns. Combining these together, M. de Tilly acknowledges that, in a distance of 1500 metres, an error might occur of 117 metres—in a distance of 2500, an error of 273 metres. This being the case, however much we may admire M. de Tilly's ingenuity, we cannot consider his suggestions to be of practical value.

The other instruments to which I alluded above, viz: those of Professor Piazzi Smyth, Lieutenant-Colonel Clerk, R. A., and of M. Otto Struve, are designed on the principle of binocular vision, consisting, in fact, of two telescopes, with which simultaneous observations are taken at the opposite extremities of a fixed base line. They differ from each other only in the details of their construction. The following is a brief description of Lieutenant-Colonel Clerk's instrument: The rays of light from the object are intercepted at each extremity of a tube by an object-glass, whose focal length slightly exceeds the half-length of the instrument. The pencils of rays are reflected by mirrors, along the tube to the centre, where they are again received by other reflectors, so placed as to throw the two images into the focus of a common eye-piece, so that they can be seen simultaneously by one observer. In the focus of the eye-piece are two vertical hairs, one fixed, the other movable by means of a micrometer screw, by which the interval between the two images can be measured with great delicacy. The distance of the objects is estimated, as I have before stated, by the angle subtended at the object by the rays of light passing from any point in the object to the two object glasses of the instrument. This angle is obtained from the following equation:

$$\text{Sine } \theta = \frac{\text{distance of movable hair from its position when instrument is set to infinity}}{\text{focal length of object glass.}}$$

These instruments are exceedingly beautiful, both in design and in construction; but they are of very delicate construction, and great care and nicety are required to obtain trustworthy observations. They can, therefore, only be put into the hands of an expert observer. For comparatively short distances they are exceedingly correct, distances of two and three hundred yards being measured to within a few inches, which is greater accuracy than is usually attained by ordi-

nary chaining. Such instruments are therefore likely to be of great value in land surveying, and they have, I believe, been applied to that purpose in Russia. But it still remains to be decided whether observations depending on twice-reflected images are to be relied on for the long ranges, and under the ordinary circumstances of military service. At great distances the twice-reflected images lose much of their sharpness of outline, and the two images being in very close proximity, if not overlapping each other, the greatest nicety is required to measure the interval between them. Strong light—not always attainable in our climate—is also indispensable, so much being lost in the double reflection. A very great source of error, against which it is difficult to guard, is any unequal expansion in the tube of this class of instrument from alteration in the temperature, or the direct influence of the sun, any amount of curvature, however minute, altering the angles of the mirrors and causing a very considerable error. If, however, an observation can be taken of some object at a known distance, either immediately before or immediately after making the required observation, the necessary amount of correction may be ascertained. But this entails a loss of time, and is not in all cases practicable.

Professor Piazzi Smyth and M. Otto Struve each constructed instruments upon a similar plan to this, and, singularly enough, though working independently, they both selected five feet as the length of their base. Lieutenant-Colonel Clerk's first instrument had a base of two feet. Mr. Adie, instrument maker in the Strand, exhibited a similar instrument at the Aldershot, in May, 1864,* having a base of 18 inches; it was stated to be efficient to 1500 yards, and its price was £8 8s. With an instrument 3 feet long, costing £12 12s., Mr. Adie expects to be able to measure distances up to 3000 yards; and with an instrument carrying a base of 6 feet, he is confident of securing the fairly accurate measurement of distances of seven or eight miles. This anticipation may be accepted *quantum valeat*, as it has not been established by experience, and certainly strikes one as chimerical. A very beautiful instrument of Lieutenant-Colonel Clerk's design, having a base of 73·6 ins., is now under trial, and therefore until this, as well as Mr. Adie's improvements, have been fully tested, it may be considered premature to express any definite opinion concerning the utmost capabilities of this class of instruments.

(To be continued.)

Strength of Timber Beams. By Wyatt Papworth.

From the London Builder, No. 1202.

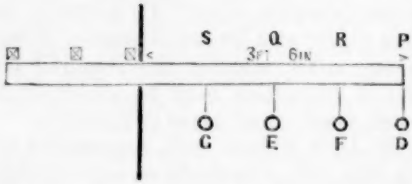
Herewith I forward, for insertion in the *Builder*, the results of some few experiments recently made by me upon the strength of beams, to

* Professor Smyth's instrument was constructed in 1855, and Lieutenant-Colonel Clerk's in 1858. Mr. Adie patented his instrument on 10th February, 1860, and registered improvements on 4th March, 1863. Mr. Adie employs prisms for reflecting, instead of mirrors; and, in place of having hairs in the eye-piece, he has one of the object-glasses in a movable frame, by which means the two images are made to coincide, and the angle of the object-glass is then noted.

find a *practical* reply to the question put by "A Student," in page 878 of last year's volume.

A piece of yellow fir, 7 feet 6 inches in length, and 2 inches square, was placed to represent a beam with its ends loose, having a clear span of 7 feet between the supports. Two weights, ¾-cwt. each, were suspended as close as possible at the middle of the length. The deflection just exceeded an inch, being $\frac{21}{20}$. I call this experiment A. When the two ¾-cwts. were placed half-way between the middle and one of the supports, the beam deflected at that point $\frac{13}{20}$; this I call B. When but one of the ¾-cwts. was placed there, it deflected at that point only $\frac{7}{20}$; this I call C.

The piece of wood was then shifted so as to project as an arm for half its length, or 3 feet 6 inches only. A rough diagram will explain the succeeding operations. One ¾-cwt. was placed at D, or *half the weight* applied in the case of A. The beam instantly deflected $\frac{40}{20}$, or just upon *double* of A. But noticing that the fixed half of the beam was being unduly strained, I had the arm shifted to a better bearing, and secured still more firmly. On being tested again with the same weight, it deflected $\frac{36}{20}$, or *almost three-quarters more* than that of the beam A.



Applying the same weight at E, that is, in the middle of the length of the arm, the arm deflected at that point $\frac{12{\cdot}5}{20}$. With the like weight placed at F, the deflection at that point was $\frac{21{\cdot}5}{20}$. With the same weight at G, the deflection at that point was $\frac{5}{20}$.

Again placed loose on its supports, 7 feet apart, the beam was loaded at two points dividing the length into three equal parts; the deflection in the middle of the length of the beam was $\frac{10}{20}$, with one ½-cwt. at each point (H). But with the ¾-cwt. at each point, the deflection was $\frac{18}{20}$ (I). The beam was, as a last trial, again proved with the weights as in A, with the same result as at first, indicating that the elasticity had not been affected, and that no deduction for loss of power is to be made from the various results.

The two main results, then, are—1. That the beam deflected $\frac{21}{20}$ with 1½ cwt.; and 2, that the arm of half the length deflected $\frac{36}{20}$ with ¾-cwt., or equal to 1·8 inch.

Not having Fenwick's work mentioned by Mr. Tarn, (page 895 of last year's volume,) I cannot work out the formula given by him, as the letters E and I are not explained; but Gregory's "Mechanics for Practical Men," edit. 1862, page 388, gives the formula $\frac{432 \cdot l^3 \cdot w}{m \cdot b \cdot d^3} = D$. Working this out in the case of the beam in question, I obtain

the formula in figures $\left\{\frac{432 \times 343 \text{ feet} \times 168 \text{ lbs.}}{2{,}016{,}000 \text{ lbs.} \times 2 \text{ inches} \times 8 \text{ inches}}\right.$ (red or yellow fir) $= \text{D}$, or deflection in inches; that is, deflection = ·77175. Or, if 1,460,000 for m be taken, as given as the lowest quantity for red pine, by Rankine, in "Civil Engineering," the result is 1·065, a quantity not differing so very much from the experiment, which showed a full inch.

Now, where does science teach me the amount of the deflection of the arm? Barlow said, until 1851, that it would be *double* the deflection of the beam: then ·77175 × 2 = 1·54350; and 1·065 × 2 = 2·130, neither of which results is very satisfactory with the actual fact of 1·8 inches. The new edition (1851) of Barlow says, that the deflection of the arm will be *equal* to that of the beam; but the experiment clearly contradicts this authority. I am, therefore, inclined to put entire faith in the result given from numerous experiments made with perfect apparatus by Barlow, which does not seem to have been affected by other researches during his lifetime, and to take the *double* as the safest guide.

Not being thoroughly satisfied with experimenting with one piece of timber, I have tried another, of a different size and somewhat different material, the opportunity and material for both having been obligingly furnished by Mr. Henry Burton, on his premises at Aldersgate Street. This second beam was provided as memel, 10 feet in length, 2 inches wide, and 3 inches deep, being slightly more than the proportion of 5 : 7,—that of the strongest form for a beam. The clear span was 9 feet; and, with the ends loose as before, the beam deflected $\frac{1}{2}\frac{3}{0}$ of an inch with 1½ cwt. in the middle (L). With a ¾-cwt. placed at one-third of the length from each support, the deflection in the middle was $\frac{7{\cdot}5}{20}$ (M). With 1½ cwt. placed at one-third from one support the deflection was, at that point, $\frac{7}{2}\frac{}{0}$ (N); while at the middle the deflection was $\frac{8}{2}\frac{}{0}$ (O).

With regard to the arm, one part, 5 feet 6 inches long, was securely fixed, when the projecting portion, 4 feet 6 inches, deflected, with ¾-cwt. at P, (as in above diagram,) $\frac{23{\cdot}5}{20}$ inches, *or just about three-quarters* $\left(=\frac{23{\cdot}75}{20}\right)$ *more* than that of the beam L. The same weight at Q gave a deflection of $\frac{5{\cdot}25}{20}$ at that point; at R, of $\frac{1}{2}\frac{2}{0}$ at that point; at, S of $\frac{2{\cdot}33}{20}$ at that point.

Two main results of this experiment, then, are—1. That the *beam* deflected $\frac{1}{2}\frac{3}{0}$ with 1½ cwt.; and 2, that the arm of half the length deflected $\frac{23{\cdot}5}{20}$ with ¾ cwt. or 1·17 inch.

Working out the deflection L, with the formula as above given, we have $\frac{432 \times 729 \text{ feet} \times 168 \text{ lbs.}}{1{,}460{,}000 \text{ lbs.} \times 2 \text{ inches} \times 27 \text{ inches}}$ = deflection or ·67, and

the actual experiment gives ·65; but it must be noticed that I have again used the lowest modulus of elasticity for red pine, not memel, as given by Rankine. Using the figures 1,957,750, as given by Tredgold for memel, the resulting deflection is ·500. The inference might be drawn that the piece of wood was a weak specimen of memel. I was glad to find that the two sets of experiments agree. But if any of your readers think that I could have carried them further, possibly they will spend an hour or two on an improved series, and communicate the result. But perhaps this *practical* reply will be found a satisfactory answer to the question so usefully propounded by "A Student," who will now probably be led to doubt the accuracy of the "thorough *mathematical* investigation" on which Fenwick, according to Mr. Tarn, arrived at conformity with the statement of the new edition of Barlow's *Treatise on the Strength of Timber*, 1851, which renders that edition of questionable utility from the necessity for making corresponding alterations in the text. Perhaps, however, some scientific friends may be able to explain wherein lies the difference of the results of the carefully executed experiments with those of the mathematical investigations.

MECHANICS, PHYSICS, AND CHEMISTRY.

From the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, C. E.

(Continued from Vol. L., page 187.)

In the September number of this *Journal*, Vol. L., pages 181 to 187, I gave a table of the calculated breaking weights of 288 hollow uniform cylindrical pillars of cast iron, both ends being flat and firmly fixed; together with the calculated values of W, c, and Y, from the formulas of the late Mr. Hodgkinson,

$$W = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}},$$

$$Y = \frac{W\,c}{W + \frac{3}{4}c}.$$

A communication "On the Strength of Cast Iron Pillars," by Mr. G. P. Randall, dated from Chicago, August 24, 1860, was published in the *Architects'* and *Mechanics' Journal*, September 15, 1860, (Vol. II.,) which does not appear to me calculated to be "a valuable table for reference for builders, foundrymen, and others." On the contrary, it is more likely to mislead any person that would be simple enough to rely upon it for accuracy in all its detail, without first making his own calculations, although I do not suppose that any architect or foundryman of experience would. The formula given by Mr. Hodgkinson, and to which Mr. Randall refers, is decidedly intended for

TABLE *showing the weight of "perfect safety," in tons, according to Mr. Randall's instructions, being one-third of the breaking weights as given in his Table.*

Diameter of column in inches.	Thickness of metal. Inch.	Length of the Column in Feet.																							
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
3	½	17·	14·	11·66	10·	8·66	7·4	6·66	6·	5·33	3·66	4·33	4·	3·66	3·	3·	2·66	2·66	2·33
4	½	39·66	32·66	27·	23·33	20·	17·33	15·33	13·66	12·33	11·	10·33	9·	8·33	7·66	7·	6·66	6·	5·66
5	½	75·	68·33	50·66	43·66	38·	33·	29·	25·66	23·	21·	19·	17·33	15·66	14·66	13·66	12·33	11·66	10·66
6	½	125·	102·33	85·66	72·66	63·	54·66	48·33	43·	38·33	34·66	31·66	28·33	26·33	24·33	22·33	20·66	19·33	18·
7	¾	260·66	213·33	178·66	151·66	131·33	114·33	100·66	89·66	80·33	72·66	65·66	60·	55·	50·66	46·66	43·33	40·33	37·66
8	¾	380·	311·	260·	222·33	191·33	167·	147·33	130·66	117·	105·66	95·66	87·33	80·	73·66	68·	63·	58·66	55·
9	¾	527·33	431·66	361·33	307·	265·66	231·33	203·66	181·33	162·33	146·33	132·66	121·33	111·	102·33	94·33	87·66	81·33	76·
10	¾	705·	577·33	482·	410·66	355·33	309·33	272·33	242·33	217·	196·	177·66	161·66	148·66	136·66	126·33	117·	109·	102·33
11	1	1149·33	949·33	787·	669·33	579·	504·33	444·	395·	354·	319·	289·66	264·33	242·33	223·	206·	191·	177·66	165·66
12	1	1464·	1198·66	1002·33	852·66	737·33	642·33	569·33	502·33	450·66	406·66	369·	336·33	308·33	284·	262·33	243·	226·33	211·
13	1	1826·33	1495·	1250·33	1063·66	919·66	801·	705·33	627·33	562·33	507·	460·33	419·66	384·66	354·	327·33	303·33	280·66	263·33
14	1	2238·33	1832·33	1532·33	1303·33	1127·33	995·	864·66	769·33	689·	621·66	564·	514·66	471·66	434·	401·	371·66	346·	322·66
15	1¼	3·333·	2646·66	2213·66	1882·66	1628·33	1418·	1249·	1111·33	995·33	897·66	814·	743·	681·33	627·	579·33	537·	499·66	466·33
16	1¼	3865·33	3162·66	2653·	2251·	1947·	1695·33	1493·	1328·33	1190·	1073·66	974·	888·66	814·33	749·33	692·33	642·	597·	556·33
17	1¼	4565·33	3737·	3125·66	2658·66	2299·33	2002·33	1763·	1569·	1405·66	1268·	1150·66	1049·66	962·	885·33	818·	758·33	705·33	658·33
18	1¼	5339·	4371·66	3656·	3109·66	2689·66	2342·33	2062·66	1836·	1644·	1483·	1345·66	1227·33	1125·	1035·33	957·33	887·	825·	769·66

TABLE *from my calculations, showing the assumed safe weight, in tons, being one-fourth of the computed breaking weight from Mr. Hodgkinson's formulas as given in my tables for Hollow Uniform Cylindrical Pillars of Cast Iron, both ends flat and firmly fixed.* See pages 181 to 187, Vol. L., of this *Journal.*

Diameter of the pillar in inches.	Thickness of metal, Inch.	Length of the Pillar in Feet.																	
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
3	½	12·60	10·49	8·77	7·46	6·43	5·61	4·95	4·4	3·94	3·55	3·22	2·94	2·69	2·48	2·29	2·12	1·98	1·84
4	½	25·01	21·95	19·39	17·23	14·98	13·07	11·52	10·25	9·18	8·28	7·52	6·85	6·28	5·78	5·34	4·95	4·61	4·30
5	½	40·23	35·96	32·26	29·05	26·27	23·85	21·73	19·35	17·34	15·64	14·19	12·95	11·87	10·92	10·09	9·36	8·70	8·12
6	½	57·31	52·02	47·30	43·11	39·39	36·09	33·15	30·54	28·22	26·03	23·62	21·54	19·74	18·17	16·79	15·57	14·78	13·51
7	¾	106·64	97·77	89·71	82·43	75·86	69·95	64·64	59·86	55·55	51·67	48·16	44·95	41·2	37·92	35·03	32·48	30·22	28·19
8	¾	134·93	125·08	115·93	107·5	99·77	92·70	86·25	80·37	75·01	70·12	65·67	61·6	57·88	54·47	51·63	47·32	44·02	41·06
9	¾	164·04	153·46	143·46	134·08	125·35	117·32	109·83	102·88	96·52	90·67	85·28	80·31	75·74	71·52	67·63	64·03	60·7	57·01
10	¾	193·66	182·55	171·88	161·75	152·19	143·21	134·82	127·	119·72	112·95	106·67	100·84	95·43	90·41	85·74	81·4	77·38	73·61
11	1	288·32	273·14	258·42	244·31	230·87	218·15	206·16	194·9	184·34	174·47	165·26	156·65	148·62	141·13	134·14	127·61	121·52	115·83
12	1	328·39	312·83	297·60	282·82	268·61	255·03	242·1	229·86	218·29	207·38	197·12	187·48	178·42	169·92	161·94	154·45	147·43	140·84
13	1	368·6	352·82	337·21	321·93	307·10	292·8	279·09	265·99	253·52	241·69	230·48	219·87	209·86	200·4	191·48	183·07	175·14	167·66
14	1	408·91	392·99	377·13	361·48	346·16	331·29	316·91	303·09	289·84	277·18	265·12	253·64	242·84	232·38	222·58	213·28	204·48	196·15
15	1¼	549·11	529·19	509·22	489·41	469·92	450·89	432·41	414·55	397·35	380·84	365·04	349·94	335·54	321·83	308·78	296·38	284·59	273·4
16	1¼	599·49	579·56	559·45	539·38	519·52	500·	480·93	462·39	444·44	427·11	410·44	394·43	379·09	364·41	350·39	337·	324·22	312·05
17	1¼	649·82	629·95	609·79	589·55	569·41	549·51	529·96	510·85	492·26	474·22	456·79	439·96	423·77	408·21	393·29	378·98	365·29	352·18
18	1¼	700·11	680·33	660·17	639·84	619·5	599·31	579·38	559·81	540·67	522·02	503·92	486·37	469·42	453·06	437·31	422·16	407·6	393·63

TABLE *from my calculations, showing the assumed weight of "perfect safety," in tons, being one-tenth of the computed breaking weight, from Mr. Hodgkinson's formulas as given in my tables for Hollow Uniform Cylindrical Pillars of Cast Iron, both ends being flat and firmly fixed.* See pages 181 to 187, Vol. I., of this *Journal*.

Diameter of the pillar in inches	Thickness of metal. Inch.	LENGTH OF THE PILLAR IN FEET.																	
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
3	½	5·04	4·19	3·5	2·98	2·57	2·24	1·98	1·76	1·57	1·42	1·29	1·17	1·07	0·99	0·91	0·85	0·79	0·73
4	½	10·	8·78	7·75	6·89	5·99	5·23	4·61	4·1	3·67	3·31	3·	2·74	2·51	2·31	2·15	1·98	1·84	1·72
5	½	16·00	14·38	12·9	11·62	10·5	9·54	8·69	7·74	6·93	6·25	5·67	5·18	4·74	4·37	4·03	3·74	3·48	3·24
6	½	22·92	20·81	18·92	17·24	15·75	14·43	13·26	12·21	11·28	10·41	9·44	8·61	7·89	7·27	6·71	6·22	5·79	5·4
7	¾	42·65	39·11	35·88	32·97	30·34	27·98	25·85	23·94	22·22	20·66	19·26	17·98	16·48	15·16	14·01	12·99	12·08	11·27
8	¾	53·97	50·03	46·37	43·	39·9	37·08	34·5	32·14	30·	28·05	26·27	24·64	23·15	21·78	20·41	18·92	17·6	16·42
9	¾	65·61	61·38	57·38	53·63	50·14	46·93	43·93	41·15	38·61	36·26	34·11	32·12	30·29	28·61	27·06	25·61	24·28	22·8
10	¾	77·46	73·02	68·75	64·7	60·87	57·28	53·92	50·8	47·88	45·18	42·67	40·33	38·17	36·16	34·29	32·56	30·95	29·44
11	1	115·33	109·25	103·37	97·72	92·34	87·26	82·46	77·96	73·73	69·79	66·1	62·66	59·45	56·45	53·65	51·04	48·61	46·33
12	1	131·35	125·13	119·04	113·13	107·44	102·01	96·84	91·94	87·31	82·95	78·85	74·99	71·36	67·96	64·77	61·78	58·97	56·33
13	1	147·44	141·12	134·88	128·77	122,84	117·12	111·63	106·39	101·41	96·67	92·19	87·95	83·94	80·16	76·59	73·23	70·05	67·06
14	1	163·56	157·19	150·85	144·59	138·46	132·51	126·76	121·23	115·93	110·87	106·04	101·45	97·13	92·95	89·03	85·31	81·79	78·46
15	1¼	219·64	211·67	203·68	195·76	187·97	180·35	172·96	165·82	158·94	152·33	146·01	139·97	134·21	128·73	123·51	118·55	113·83	109·36
16	1¼	239·79	231·82	223·78	215·75	207·8	200·	192·37	184·95	177·77	170·84	164·17	157·77	151·63	145·76	140·15	134·8	129·69	124·82
17	1¼	259·93	251·98	243·91	235·82	227·76	219·8	211·98	204·34	196·9	189·68	182·71	175·98	169·5	163·28	157·31	151·59	146·11	140·87
18	1¼	280·04	272·13	264·07	255·93	247·8	239·72	231·75	223·92	216·26	208·8	201·56	194·55	187·76	181·22	174·92	168·86	163·04	157·45

similar pillars, as referred to in his paragraph, namely, 10 feet long, and from 2½ to 4 inches diameter; but Mr. Randall has overlooked this important fact.

It is absurd even to suppose that Mr. Hodgkinson ever intended the formula used by Mr. Randall to apply to the strength of a pillar 18 inches diameter and its height only 5⅓ times its diameter.

These tables, I presume, will be of some benefit to many persons who are incapable of making calculations of the strength of uniform hollow cylindrical cast iron pillars, and others who, from apparent carelessness or want of information on this important subject, have not set their pillars as they ought to be, and to enable them and all others to guard against failure in future operations. They may also be useful to some architects and civil engineers.

I will take this opportunity of here giving a few extracts, with some alteration, from what I have before given to the public. In how few cases are the iron pillars supporting heavy weights scientifically or correctly erected. Numerous are the instances of the irregularity of the manner in which they are fixed or placed in position; hundreds of them never squared on their ends, or at right angles to the axis of the pillar; many of them with pieces of iron wedges at one corner (when the bases or plinths are square); the other corners, perhaps, on a stone plinth or top of a stone pier, partly dressed with the chisel, and wholly unsupported in the centre. The necessity of squaring the ends perfectly has been shown, by Mr. Hodgkinson's experiments, to be of the utmost importance.

If a cast iron hollow cylindrical pillar, properly squared and fitted on the ends or turned in the lathe, will sustain a breaking weight of 170 tons, and another of the same dimensions, imperfectly set, (or in the usual manner,) will sustain only 50 tons, the loss of strength is quite evident; in the first case, the assumed safe load should not be more than about 42½ tons; and in the second, 12½ tons.

Pillars imperfectly set cause a great loss of material, by not squaring or fitting their ends properly, requiring about four times as much material to be used in their construction than is absolutely necessary; whereas, the cost of fitting them accurately on their ends cannot, in any case, equal the cost of the loss of the material.

On inspection of Mr. Randall's table it will be seen that a hollow cylindrical pillar of cast iron, 8 feet in length or height, 18 inches external diameter, with a thickness of metal of 1¼ inches, and whose height is equal to 5⅓ times its diameter, is calculated to sustain a breaking weight of 16,017 tons. This would be sufficient to sustain a solid pillar of cast iron of 8½ miles high.

Mr. Randall in his table has given the breaking weights of 288 pillars, 76 of which only are correct as regards the breaking weight, being a little more than one-quarter of the whole table. On reference to Mr. Randall's table, any one can perceive, at a glance, its incorrectness; for instance, for a hollow cylindrical pillar, 8 feet long and 17 inches diameter, thickness of metal 1¼ inch, he gives the breaking weight at 13,696 tons, and for another of the same length and 18 inches diameter, he gives 16,017 tons, which is an increase of 2321

tons, or enough for the whole pillar to support, being 1621 tons more than the assumed safe load, as will be seen by the result of my calculation given in my tables.

I have seen many pillars of different materials that were bent under a superincumbent weight, and if these had been properly calculated bending should not have taken place. I here instance four cast iron pillars about 12½ feet high and 5 inches external diameter, supporting a cut stone front 20×40 feet; and after the building was erected, I observed that the pillars were deflected about ½ or ¾ of an inch in their height, which plainly shows that they are not sufficiently strong for the building; how much more additional weight than the front that they have to support, I am not prepared to say, but one of the pillars being at the angle of a street, has an additional duty to perform in supporting about four feet of the flank wall; these pillars are irregularly fixed, and I doubt not but that they were erected without making any calculation.

Mr. Randall, in his table already referred to, has given the breaking weight of a pillar 8 feet high, 18 inches external diameter, 15½ inches internal diameter, or 1¼ inch thickness of metal, calculated at 5½ times its diameter to sustain a weight of 16,017 tons, equal to a solid pillar of the same material and same external diameter of 79,729 cubic feet. Taking the specific gravity of cast iron at 7209 or 450 lbs. to the cubic foot, will give us a solid pillar of the same material, 18 inches diameter, of 45,300 feet high, or about 8½ miles; thus 16,017 × 2240 = 35,878,080 ÷ 450 lbs. in a cubic foot of cast iron = 79,729 cubic feet in 16,017 tons of cast iron, and 79,729 ÷ 1·76 foot = the area of the base of 18 inches diameter, is equal to 47,300 lineal feet for the height of the solid cylinder, and 45,300 ÷ 5280 feet (the number of feet in a mile) produces 8·57 miles for the height; or, in other words, it will sustain a solid rock or cube of granite whose sides are 60 feet = 216,000 cubic feet.

It will be found by my calculations for the above pillar, that the breaking weight is 2800 tons, which is nearly six times less than Mr. Randall's; the assumed safe weight would be about 700 tons, which is quite enough, in all conscience, to expect it to support. (The assumed weight of perfect safety, 280 tons.) The weight of "perfect safety" of Mr. Randall's would be, according to his instructions, 5339 tons, or about seven and a half times too great for the assumed weight of safety, and twenty times too great for perfect safety.

Solid Uniform Cylindrical Pillars of Red Deal, both ends being flat and firmly fixed.

Length or height of pillar in feet.	Diameter in inches.	Value of w in tons from formula $w = 4{\cdot}79 \frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formulas $w = 4{\cdot}79 \frac{D^4}{L^2}$ $Y = \frac{w\,c}{w + \frac{3}{4}c}$
8	15	3788·96	519·54	471·11
35	"	197·95	"	175·02

Hollow Uniform Square "Box" Pillars of Red Deal, both ends being flat and firmly fixed.

Length or height of pillar in feet.	External side of the square in inches.	Internal side of the square in inches.	Value of w in tons from formula $w = 7{\cdot}81 \frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formulas $w = 7{\cdot}81 \frac{D^4}{L^2}$ $Y = \frac{W c}{W + \frac{3}{4} c}$
6	4	2	52·06	35·28	23·89
7	"	"	38·04	"	20·80
8	"	"	29·28	"	18·53
9	"	"	23·14	"	16·45
10	"	"	18·74	"	14·62
11	"	"	15·49	"	13·02
12	"	"	13·01	"	11·62
13	"	"	11·09	"	10·41
14	"	"	9·56	"	9·36
			Calculated breaking weight from the above formula.		
15	"	"	8·33		
16	"	"	7·32		
17	"	"	6·48		
18	"	"	5·78		
19	"	"	5·19		
20	"	"	4·68		
			Value of w.		
1	12	8	129958·4	235·2	234·88
2	"	"	32489·6	"	233·92
3	"	"	14439·82	"	232·36
4	"	"	8122·4	"	230·20
5	"	"	5198·33	"	227·48
6	"	"	3609·95	"	224·24
7	"	"	2652·21	"	220·53
8	"	"	2030·6	"	216·40
9	"	"	1604·42	"	211·90
10	"	"	1299·58	"	207·09
11	"	"	1074·03	"	202·01
12	"	"	902·48	"	196·74
13	"	"	768·98	"	191·31
14	"	"	663·05	"	185·77
15	"	"	577·59	"	180·17
16	"	"	507·65	"	174·54
17	"	"	449·68	"	168·93
18	"	"	401·1	"	163·35
19	"	"	359·99	"	157·85
20	"	"	324·89	"	152·43
21	"	"	294·69	"	147·12
22	"	"	268·5	"	141·94
23	"	"	245·66	"	136·89
24	"	"	225·62	"	131·99
25	"	"	207·93	"	127·24
8	14	8	4188·11	388·08	362·86
10	"	"	2680·39	"	350·06
12	"	"	1861·38	"	335·60

The following table, which gives the results of some forty-one experiments that I have recently made on small cubes and pillars of timber, and indicates the strength of American white pine (pinus strobus) pillars, (the house carpenter's wood,) and one experiment for comparison with a spruce pillar. The pillars were very accurately squared and fitted, both ends being flat and firmly fixed, and the experiments were made in a frame constructed of oak timber, and by means of a lever compressing the ends of the pillars which stood perpendicular between two flat and even surfaces of iron, always parallel to each other, and similar to that employed by the late Mr. Eaton Hodgkinson in conducting his experiments.

The pillars were all cut out from the one piece of timber, well seasoned and dried in a room with moderate heat from a stove, and the experiments were conducted in the open air.

I also found, from experiment, the following result: that, of two pillars, one of spruce and the other of pine, both of the same dimensions, namely, three feet high and one inch square, whereas the pine was completely crippled by 1237 lbs., that of the spruce, with a weight of 1514 lbs., remained uninjured and without visible sign of deflection.

The remarks, in the column of remarks in the table, are set down as registered at the time of making the experiments exactly as written down by Mr. John Nader, who assisted me in making them.

TABLE *showing the Breaking Weights of Solid Uniform Square Pillars of American White Pine, strength per square inch of section and the calculated breaking weight of the Pillars from the following formulas, both ends being flat and firmly fixed.*

$$w = 11133 \frac{D^4}{L^2} \qquad Y = \frac{w + \frac{3}{4} c}{w\ c}$$

Number of experiments.	Length or height of pillar in inches.	Side of the square—inch.	Breaking weight in lbs.	Strength per square inch of section in lbs.	Calculated break'g weight in lbs. from formula $w = 11133 \frac{D^4}{L^2}$	Calculated break'g weight in lbs. from formulas $w = 11133 \frac{D^4}{L^2}$ $Y = \frac{w\ c}{w + \frac{3}{4} c}$	Remarks.
1			1145	4580			Crushed down.
2			1145	4580			" "
3			914	3656			Yielded laterally.
4			914	3656			" "
5			1100	4400			Crushed by sliding.
6			1100	4400			" bending.
7	1	"	1390	5590		1409	" top and bottom.
*8	1	"	1440	5760		1403	" by sliding.
9	1	"	1440	5760		1409	" "
10	2	"	1390	5560		1367	" top and bottom.
†11	2	"	1340	5360		1367	" by sliding.
12	2	"	1340	5360		1367	" "
13	3	"	1284	5136		1309	" bending.

Number of experiments.	Length or height of pillar in inches.	Side of the square—inch.	Breaking weight in lbs.	Strength per square inch of section in lbs.	Calculated break'g weight in lbs. from formula $W = 11133\frac{D^4}{L^2}$	Calculated break'g weight in lbs. from formulas $W = 11133\frac{D^4}{L^2}$ $Y = \frac{W c}{W + \frac{3}{4} c}$ *	Remarks.
14	3	"	1284	5136		1300	Crushed by bending.
15	4	"	1390	5560		1217	" "
16	4	"	1284	5136		1217	" "
17	5	"	1116	4464		1125	" "
18	5	"	949	3796		1125	" "
19	6	"	822	3288		1029	" "
20	6	"	776	3104		1029	" "
21	7	"	868	3472		936	" "
22	8	"	776	3104		847	" "
23	9	"	706	2824		764	" "
24	9	"	799	3196		764	" "
25	10	"	753	3012		689	" "
26	11	"	729	2916		622	" "
27	12	"	580	2320		561	" "
28	12	"	568	2272		561	" "
29	13	"	453	1812		508	" "
30	14	"	453	1812		460	" "
31	15	"	453	1812		418	" "
32	16	"	424	1696		383	" "
33	36	$\frac{3}{4}$	453	604	391		*
34	36	1	1237	1237	1237		†
35	24	1	2368	2368		2247	‡
36	18	$\frac{3}{4}$	218	872	308		Broke very suddenly.
37	18	$\frac{7}{8}$	1635	2180	1565		" slowly.
38	18	"	1380	1840	1565		" suddenly.
39	18	"	1422	1896	1565		" very slowly.
40	18	"	1700	2266	1565		" suddenly.
41	24	$\frac{1}{2}$	120				This pillar, when set up, was inclined from the perpendicular one-quarter of its height.

NOTES.

				Deflect'n inch.	Deflecting weight in lbs.		
*33	36	$\frac{3}{4}$	453	$\frac{1}{8}$	168·5		This pillar deflected $1\frac{1}{4}$ inch with 453 lbs., and would have broken had not the bottom of the scale platform rested on ground.
				$\frac{3}{8}$	314·5		
				$1\frac{1}{2}$	360·5		
				$\frac{3}{4}$	406·8		
				$\frac{7}{8}$	453		
				$1\frac{1}{8}$	453		
†34	36	$\frac{3}{4}$	1237	$\frac{1}{4}$	591		This pillar broke slowly and yielded diagonally.
				$1\frac{3}{8}$	960		
				$\frac{1}{2}$	1237		
				$1\frac{1}{4}$	1237		
‡35	24	1	2368				This pillar, with this weight, broke suddenly.

Mr. Rennie found that to crush a cube of one inch on the side, the weight in pounds required were as under:

English oak,	3860 lbs.
White deal,	1928 "
American pine,	1606 "
Elm,	1284 "

According to M. Rondelet, a piece of timber diminishes in strength as it begins to bend, so that the mean strength of the wood of the oak, which is 44 lbs., French, for every line superficial in the case of a cube, is reduced to 2 lbs. for a piece of the same wood when its height is 72 times its base. From a great number of experiments he compiled the following progression:

In a cube, the height of which is			1,	the strength is	1·
In a piece, the height of which is			12,	"	·833
"	"	"	24,	"	·5
"	"	"	36,	"	·33
"	"	"	48,	"	·166
"	"	"	60,	"	·083
"	"	"	72,	"	·041

Thus, in a cube of oak of 1 inch superficial of base, submitted to the action of a force pressing vertically, the mean force is expressed by $144 \times 44 = 6366$. While the mean of experiments gave 6346

In a bar of the same wood of the same base, and 12 inches high, the strength by the progression would be $144 \times 44 \times \cdot 333 = 5278$. " 5310

In a bar 24 inches high, the strength by the formula $144 \times 44 \times \cdot 5 = 3168$. " 2911

In a bar 36 inches, the strength by the formula $144 \times 44 \times \cdot 333 = 2110$. " 2163

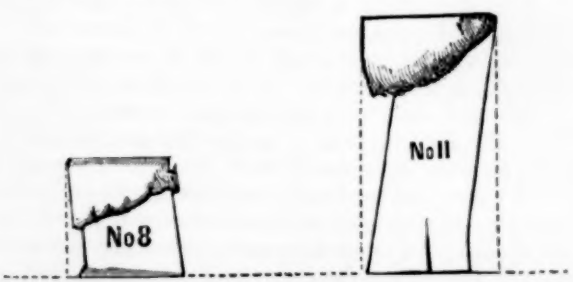
In a bar $48 = 144 \times 44 \times \cdot 134 = 849$.
In a bar $60 = 144 \times 44 \times \cdot 083 = 526$.
In a bar $72 = 144 \times 44 \times \cdot 042 = 266$.

In fir bars the following results were obtained:

	By Calculation.	By Experiment.
In a cube of 1 inch, $144 \times 52 \times 1\cdot$	$= 7488$	7490
In a bar of 12 inches, $144 \times 52 \times \cdot 833$	$= 6238$	6355
" 24 " $144 \times 52 \times \cdot 5$	$= 3744$	3429
" 36 " $144 \times 52 \times \cdot 33$	$= 2471$	2575

These results, M. Rondelet observes, accord with the experiments of MM. Perronnet, Lamblardie and Girard.

NOTE.—* † *Diagram of the experiments Nos.* 8 *and* 11, page 319.—*Full size.*



The original specimens experimented upon are in the possession of the Franklin Institute, together with ten other specimens of the experiments.

In an experiment described by the latter, a piece of wood 2 metres 273 millemetres long, and 155 by 104 millemetres in section, broke under a weight of 33,120 kilogrammes.

Reducing these to English measures, the length is 7·35 feet, the section of base 6·05 by 4·06 inches. The area of section = 24·563 inches, and as the weight is 72,864 lbs., the weight on the square inch is 2966 lbs.

The height of the piece is about twenty-two times the size of the base, and the progression would give a reduction of half the strength. If, therefore, 2966 is doubled, 5932 lbs. are obtained as the absolute resistance per square inch, a result which agrees very closely with the experiments of M. Rondolet.

(To be Continued.)

The Bulletin of the Belgian Academy of Sciences reports a curious experiment of M. de Wilde, which will have an interest for our theoretical chemists. A piece of spongy platinum is introduced into hydrogen gas over mercury, and when the absorption has ceased, as is indicated by the level of the mercury becoming constant, acytelene is introduced, a very rapid absorption takes place, and new hydrocarbons are formed which have not yet been obtained in other ways.

Cosmos.

Steam Pressure Regulator of M. Eug. Rolland.

The apparatus of M. Rolland works automatically, and regulates the pressure so perfectly as not to allow it to vary more than 0·15 of an atmosphere from the mean pressure desired. It consists of a bent iron tube, with two vertical branches containing mercury,—one branch entering the steam-box through its bottom, while the other opens into the air. In the steam-box the tube terminates in a chamber of large diameter, in which is a cast iron float, made hollow so as to be as light as possible, the hollow being filled with a mixture of bitumen and sand. The steam is introduced into the box by a pipe passing through the upper cover of the box, and vertically above the axis of the mercury chamber. This steam-tube is closed at bottom, and opens into the chamber by means of a number of slots cut through its wall. A sleeve slides easily over the part of the tube in which the slots are cut, and is carried by a vertical stem connected with the float. The length of this stem is so regulated that when the pressure is below the normal the sleeve is above the slots, and the steam openings are, of course, entirely free. As the pressure increases the float descends, carrying the sleeve down over the tubes, and gradually excludes the steam from the box. In order to make the apparatus as sensitive as possible, the movement of the float should be slow so long as the pressure has not attained the normal, and should become very rapid so soon as this is slightly exceeded. This result is obtained by making the float of nearly the

same diameter as the chamber, and arranging a considerable enlargement at that part of the outside tube to which the surface of the mercury corresponds at the normal pressure.

This regulator of M. Rolland has now been in use for several years in the principal tobacco manufactories of Paris, Dieppe, &c., and has always kept the pressure within the limits above indicated. It might, however, if necessary, be made still more precise by connecting the float with a compensating counterpoised lever, such as M. R. has introduced into his thermo-regulator.

Academy of Sciences of Paris.

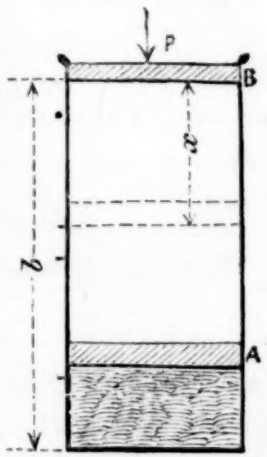
For the Journal of the Franklin Institute.

A Problem in the Conversion of Mechanical Power into Heat.

By John D. Van Buren, U. S. Naval Engineers.

Problem.—*To find how much the temperature of a given weight of air will be increased by a given gradual compression, and also the mechanical effect expended in producing this compression, supposing no loss from conduction or radiation, upon the hypothesis that heat and mechanical effect are convertible in the ratio of Joule's equivalent.*

Let the figure represent a cylinder, with a piston moving in it without friction or weight, and confining beneath it exactly *one pound of air*, by means of the compressing force P. Let the piston have an area of exactly one square foot. The problem then is: to determine the *increase of temperature* of the air due to forcing the piston from B to a given point A, and the mechanical effect expended.



Notation.

p = initial pressure in pounds per square foot exerted by the air against the piston.

p_x = pressure in pounds per square foot exerted by the air when the piston has been driven through the path x.

t = initial temperature of air in degrees Fahrenheit above 32°.

t_x = temperature of air in degrees Fahrenheit above 32°, corresponding with x, p_x and t_x.

w = weight of one cubic foot of air at temperature t and pressure p.

ρ = co-efficient of expansion for air for 1° Fahrenheit.

s = specific heat of air compared with that of water as unity.

772 = Joule's equivalent = mechanical effect in foot-pounds equivalent to the heat required to raise one pound of water 1° Fahrenheit.

x = distance through which the piston has been forced when the temperature and pressure are respectively t_x and p_x.

Now, since the work of resistance is equal to the work of the applied compressing force, we may confine our attention to the former. We may also overlook the influence of the inertia of the air, since the compression is to be *gradual* and with *uniform* velocity. Then, if the piston be forced through the *differential* path dx, from any position x, the work expended upon the piston, and converted into heat in the air, due to this motion, is in foot-pounds,

$$p_x\,dx, \qquad . \quad . \quad . \quad . \quad . \quad (1,)$$

and the temperature added to the air by this must therefore be—

$$dt_x = \frac{p_x\,dx}{772\,s}, \qquad . \quad . \quad . \quad . \quad . \quad (2.)$$

But we have, from Gay Lussac's law,

$$\frac{v}{v_x} = \frac{1+\rho t}{1+\rho t_x} \cdot \frac{p_x}{p}, \qquad . \quad . \quad . \quad (3.)$$

Where v = initial volume of air, and v_x = volume of air corresponding with p_x. Then, if b = whole length of cylinder, we shall have—

$$\frac{v}{v_x} = \frac{b}{b-x} = \frac{1+\rho t}{1+\rho t_x} \cdot \frac{p_x}{p}, \qquad . \quad . \quad (4;)$$

$$\therefore\ p_x = \frac{p\,b}{1+\rho t} \cdot \frac{1+\rho t_x}{b-x}, \qquad . \quad . \quad (5.)$$

Hence, from (2),

$$dt_x = \frac{1}{772\,s} \cdot \frac{p\,b}{1+\rho t} \cdot \frac{1+\rho t_x}{b-x} \cdot dx, \qquad . \quad . \quad (6;)$$

$$\therefore \frac{dt_x}{1+\rho t_x} = \frac{p\,b}{772\,s\,(1+\rho t)} \cdot \frac{d\,x}{b-x}, \qquad . \quad . \quad (7,)$$

or,

$$\frac{dt_x}{1+\rho t_x} - \frac{p\,b}{772\,s\,(1+\rho t)} \cdot \frac{d\,x}{b-x} = 0, \qquad . \quad (8.)$$

In (8) place the constant $\dfrac{p\,b}{772\,s\,(1+\rho t)} = a, \qquad . \quad . \quad (a;)$

$$\therefore \frac{dt_x}{1+\rho t_x} - a \cdot \frac{dx}{b-x} = 0, \qquad . \quad . \quad (9,)$$

and, integrating by the rules of integral calculus,

$$\frac{1}{\rho} \log_{.e}(1+\rho t_x) + a \log_{.e}(b-x) + c = 0, \qquad . \quad (10,)$$

where $\log_{.e}$ = Neperian logarithm.

But when $x = 0$, $t_x = t$;

$$\therefore\ c = -\frac{1}{\rho} \log_{.e}(1+\rho t) - a \log_{.e} b, \qquad . \quad (11;)$$

$$\therefore \frac{1}{\rho} \log_{.e} \frac{1+\rho t_x}{1+\rho t} + a \log_{.e} \frac{b-x}{b} = 0, \qquad . \quad (12,)$$

or,

$$\log_e \left[\frac{1+\rho t_x}{1+\rho t} \cdot \left(\frac{b-x}{b} \right)^{a\rho} \right] = 0, \quad . \quad (13.)$$

Hence,

$$\frac{1+\rho t_x}{1+\rho t} \cdot \left(\frac{b-x}{b} \right)^{a\rho} = 1, \quad . \quad . \quad (14.)$$

and, solving for t_x,

$$t_x = \left[(1+\rho t) \left(\frac{b}{b-x} \right)^{a\rho} - 1 \right] \div \rho, \quad . \quad . \quad (16.)$$

Now, introducing the value of a,

$$t^x = \left[(1+\rho t) \left(\frac{b}{b-x} \right)^{\frac{p\,b\,\rho}{772\,s\,(1+\rho t)}} - 1 \right] \div \rho, \quad . \quad (17.)$$

But $b = \frac{1}{w}$;

$$\therefore t_x = \left[(1+\rho t) \left(\frac{b}{b-x} \right)^{\frac{p\,\rho}{772\,s\,w\,(1+\rho t)}} - 1 \right] \div \rho, \quad (18.)$$

If w_0 = weight of one cubic foot of air at temperature 32° Fahrenheit, and pressure $p_0 = 14{\cdot}76 \times 144$ lbs. per square foot, then

$$w = \frac{p}{p_0} \cdot \frac{w_0}{1+\rho t}, \quad . \quad . \quad . \quad . \quad (b.)$$

Introducing (*b*) in (18) we get—

$$t_x = \left[(1+\rho t) \left(\frac{b}{b-x} \right)^{\frac{p_0\,\rho}{772\,s\,w_0}} - 1 \right] \div \rho, \quad . \quad . \quad (19.)$$

It will be observed, in (19), that t_x is independent of the pressure, since $\frac{p_0}{w_0}$ is *constant*. This is correct; for we have taken a constant weight of air, and the path of the work of compression must therefore vary inversely as the initial pressure, the initial temperature remaining the same, no matter what the degree of compression. The effect of increasing the initial temperature above 32° is observed to be to increase the temperature t_x just 100 ρt per cent. This is also correct; since, if we have the same initial pressure, the path of the work of compression is increased precisely 100 ρt per cent. by this increase of initial temperature, no matter what the degree of compression; and, therefore, the temperature t_x should also be increased by this amount, *since the increase of temperature measures the work done.* If $x = 0$, $t_x = t$; if $x = b$, $t_x = \infty$, which are correct results.

By introducing the values of ρ, ρ_0, w_0, and s, the formula becomes very simple:

$\rho = {\cdot}002039$, $\quad p_0 = 14{\cdot}76 \times 144 = 2125{\cdot}44$,
$s = {\cdot}238$, $\quad w_0 = {\cdot}081241$ lbs.;

$$\therefore t_x = \left[(1 + {\cdot}002039\,t) \left(\frac{b}{b-x} \right)^{{\cdot}290333} - 1 \right] \div {\cdot}002039$$

$$= \left[(491 + t) \left(\frac{b}{b - x} \right)^{\cdot 290333} - 491 \right] \quad . \quad (20,)$$

and, putting $\frac{b}{b-x} = r$ = degree of compression, we finally get—

$$t_x = (491 + t)\, r^{\cdot 290333} - 491, \quad . \quad . \quad (21.)$$

The mechanical effect expended, or *work* of resistance is, for w pounds of air,

$$W = 772\, s\, (t_x - t)\, w, \quad . \quad . \quad (22,)$$

$$= 183{\cdot}74\, (t_x - t)\, w, \quad . \quad . \quad (23,)$$

since every degree of temperature added must be produced by the conversion of 183·74 lbs. feet into heat.

Heat Produced by Impact.

If a force P strikes the piston moving with a velocity of v feet per second, and is brought to rest by the *cushioning* of the air, which is not allowed to rebound after the greatest compression, the work (= one-half the *living force*) of the blow is—

$$W = \frac{P\, v^2}{2g}, \quad . \quad . \quad . \quad . \quad . \quad (24,)$$

when $g = 32\frac{1}{6}$ feet, and hence the increased temperature due to this blow, and appearing in the air, is—

$$t_x - t = \frac{P\, v^2}{2 \times 772\, s\, g} = \frac{P\, v^2}{367{\cdot}472\, g} = {\cdot}0000846\, P\, v^2, \quad (25,)$$

in degrees Fahrenheit.

But, if the weight of air be w pounds, then—

$$t_x - t = {\cdot}0000846\, \frac{P\, v^2}{w}, \quad . \quad . \quad (26,)$$

when $t_x - t$ is *temperature* added, not units of heat.

A very striking instance of the conversion of mechanical power into heat is the heating to *redness in broad daylight* of an iron target when struck by a heavy shot from a cannon. The heat is often so intense as to weld the shot firmly in the target.

Examples under Equations (21), (23,) and (26).

Example 1.—Required the temperature of 10 lbs. of air after compressing it, from a temperature of 32° Fahrenheit, into one-fifth of its original volume, and the mechanical effect expended. In (21) make $t = 0$, and $r = 5$;

$$\therefore t_x = 491 \times 5^{\cdot 290333} - 491$$

$$= 292°{\cdot}4, \quad . \quad . \quad . \quad . \quad (1.)$$

$$W = 183{\cdot}74\, (t_x - t)\, w = 183{\cdot}74 \times 292{\cdot}4 \times 10$$

$$= 537255{\cdot}76 \text{ lbs. feet.} \quad . \quad . \quad . \quad . \quad (2.)$$

From this and other calculations we get—

Initial Temperature 32°, $t = 0$. Initial Temperature 132°, $t = 100°$.

Compression to one-fifth,	$t_x = 292°{\cdot}4$	$t_x = 452°{\cdot}0$
" one-tenth,	$t_x = 467°{\cdot}1$	$t_x = 662°{\cdot}2$
" one-twentieth,	$t_x = 680°{\cdot}7$	$t_x = 919°{\cdot}3$

The increase in temperature, for the six cases in order, is—

$t_x - t = 292°{\cdot}4$	$t_x - t = 352°{\cdot}0$
" $= 467°{\cdot}1$	" $= 562°{\cdot}2$
" $= 680°{\cdot}7$	" $= 819°{\cdot}3$

The temperatures above *zero*, Fahrenheit, are—

$t_x + 32 = 324°{\cdot}4$	$t_x + 32 = 484°{\cdot}0$
" $= 499°{\cdot}1$	" $= 694°{\cdot}2$
" $= 712°{\cdot}7$	" $= 951°{\cdot}3$

As a proof of the arithmetical work, to *tenths* of a degree, we have

$$\frac{352 - 292{\cdot}4}{292{\cdot}4} = \frac{562{\cdot}2 - 467{\cdot}1}{467{\cdot}1} = \frac{819{\cdot}3 - 680{\cdot}7}{680{\cdot}7} = {\cdot}204.$$

EXAMPLE 2.—A cylinder containing ten cubic inches of air, confined by a plunger-piston receives a blow upon its piston from a weight $P = 10$ lbs., moving with a velocity of 30 feet per second. Required the temperature given to the air, supposing the initial temperature 32° Fahrenheit.

$$t_x - t = \frac{{\cdot}0000846 \times 10 \times 900}{{\cdot}081241 \times \frac{10}{1728}} = 1619°{\cdot}5$$

$$t_x + 32 = 1651°{\cdot}5 \text{ Fahrenheit.}$$

This affords an explanation of the well known experiment of lighting tinder by sudden compression of air. The principles involved in equation (21) are involved in the problem of finding the amount of condensation taking place in the cylinder of a steam engine, using steam *expansively*.

The writer hopes to give a solution of this last problem at some future time, and it is with this design in view that this paper is offered for publication.

Bureau of Steam Engineering, March 20, 1866.

Water Freezing at a Depth of Twenty-five Feet.

We copy from the Detroit *Free Press* the following article, on account of the singularity of the difficulty which it sets forth, and because it may, in many cases, be of importance to engineers to be aware that such effects may occur. The explanation suggested by Prof. Douglass is undoubtedly correct, the phenomenon of ground-ice having been long known and carefully observed, and the remedy which he proposes would doubtless be effectual. It may, perhaps, be added, that, when a platform floating on the water would be in the way of navigation, a wooden shield secured a few feet above the mouth of the pipe would secure the same result.

The Water Commissioners have encountered a difficulty in obtaining water from the river in the winter, which may be considered a singular phenomenon. A brief description of the inlet pipe and nature of the difficulty may be interesting. The inlet pipe to the pump

well is made of boiler iron; it is 30 inches diameter; its extreme length is about 220 feet, and it extends into the river 150 feet from the wharf, into water 34 feet deep at the extreme end. On the river end of the pipe there is a bell-shaped mouth, elbow turned upwards, the end of which is 36 inches diameter, over and surrounding which there is a strainer, also made of boiler iron, 9 feet diameter and 10 feet high; above the end of the pipe the boiler plate in the strainer is punched with half-inch holes—144 to each square foot. Surrounding the mouth of the pipe, and inside the shell of the strainer, there is a diaphragm plate, also punched with half-inch holes. Below the diaphragm plate, the shell of the strainer is punched with four-inch holes, to allow the sand to pass through and not bank up on the outside of the strainer. The pipe is covered with a large quantity of building stone. The water is drawn from the well by a steam pumping engine, and when the engine is pumping, the water is required to pass through the holes in the strainer at the rate of 120 barrels per minute to furnish an adequate supply. The water is 25 feet deep over the top of the strainer; the current of the river is about three miles per hour.

Under certain circumstances, during extreme cold weather, it is with difficulty a supply of water can be obtained, in consequence of the accumulation of ice on the strainer, frequently requiring the speed of the engine to be reduced, and at times to stop it for several hours together, for no water passed through the pipe into the well, and the water in the well would be exhausted, notwithstanding the bottom of the well is 12 feet below the surface of the river. Size of well about 40 feet long, 18 feet wide, and 12 feet deep.

The circumstances under which the difficulty occurs, are when the weather is cold, and ice is forming in the lake above, and on the shores of the river, and the river is open free from ice over the strainer. But when the river is covered with ice over the strainer, the difficulty does not occur at any degree of cold. The greatest difficulty occurs when the thermometer ranges from 7° or 8° to 18° or 20° above zero, greater than when it is below zero, and when the mercury rises above 20°, however sudden, the difficulty immediately ceases. The greatest difficulty, it has been observed, occurs at night, and when the sun is obscured by clouds, but when the sun is unclouded no difficulty is ever experienced. This difficulty has been encountered in supplying the city with water for many years.

Dr. Pitcher addressed a letter to Professor Douglass, of the State University, enclosing one from Mr. R. E. Roberts, Secretary of the Water Commissioners, detailing the facts given above, and asking an explanation of this phenomenon. The following is the reply of Professor Douglass:

UNIVERSITY OF MICHIGAN,
January 29, 1866.

ZINA PITCHER, M. D., Detroit.

Dear Sir: Your letter, covering a communication from R. E. Roberts, Esq., in relation to the obstruction of the supply pipe at the water works in your city, was duly received, and I have given the subject careful consideration. With the facts

which the letter affords, I am unable to give an explanation of the singular phenomena entirely satisfactory to myself. Mr. Roberts states that the ice does not form on the strainer when the sun shines, but does not give the effect of a cloudless night. Probably no observations have been made. I think, however, on careful investigation, that this will be found to be the most favorable condition for the deposition of ice. Should this prove true, I should explain the phenomena upon the principle of Wells' well-known and acknowledged theory of the formation of dew, viz: by radiation.

The extremity of the pipe is a good radiator of caloric as well as a good absorber. When the water reaches about the temperature of 32°, the pipe, parting with its caloric by radiation into space, is so far reduced in temperature as to cause the water to congeal upon its surface. The clear water, being to a great extent transcalent, would not interrupt the passage of the caloric. Nor would the great depth affect it, for it is well known that caloric that has been transmitted through one layer of a transcalent medium will be transmitted through any number of layers. The rays of the sun would also convey heat through the water to the pipe, (a good absorber of caloric,) and thus dissipate the ice. As soon as the ice forms upon the river, all radiation and transmission of caloric would be stopped by the intertranscalency of the ice. Upon this theory, we should have ice most freely deposited on the strainer in clear and cloudless nights before ice has covered the river. It would also be dissipated in a cloudless day. The last seems to be true, if not the first.

Assuming this as the true theory, I would suggest the following remedy of the evil: Procure three or four large scows or a timber-raft, and have them anchored directly over the pipe. They will intercept the heat radiated from the pipe, and send it back again to the source from whence it came. If the evil is a serious one, the experiment is worthy of a trial. I think the scows will prevent the ice forming on the strainer.

Very respectfully,

SILAS H. DOUGLASS.

Apparatus for the Detection of Explosive Gases in Mines.

From the London Chemical News, No. 315.

The lamentable accidents which from time to time occur in coal mines, causing such great destruction of life and property, have engrossed the attention of scientific men ever since the results of the study of natural phenomena have been practically applied to every-day life. Numerous methods of illuminating the mines in such a manner as to prevent the ignition of the combustible gases, but at the same time producing sufficient light to enable the men to work in comfort, have been suggested and employed with varying success.

Next to preventing the accumulation and explosion of inflammable gas in the mines, the possibility of ascertaining with safety its presence is a matter of some importance, as it would enable the overseer to guard against incautious working in a dangerous part of the pit, and to prevent too great an accumulation of the explosive mixture by directing special attention to the ventilation. The process formerly employed by the miners to detect the presence of the inflammable gas, and which cannot be recommended as a safe one, was to bring a lighted candle into the suspected atmosphere, when the peculiar shape assumed by the candle flame gave the required information. This process cannot be too strongly reprehended, and it is probably the cause of many of the fearful accidents which have already taken place.

Another method, which is much more safe, but which is not unattended with danger, is to observe the flame of a Davy lamp. A careful viewer invariably reduces the flame of the Davy lamp to the smallest size that will emit white light before testing for gas, or, as he calls it, "trying a fiery place." When the atmosphere consists of a violently explosive mixture, one hears a peculiar and sharp click, and observes a rapid combustion of the gas within the wire gauze of the safety lamp; when the quantity of carburetted hydrogen is less, the flame of the lamp elongates; and when the quantity is very small, a peculiar lambent cap of a bluish color is observed covering the flame of the lamp. These indications can only be learned by experience in the mines, and, when not properly attended to, might give rise to disastrous results. Should the atmosphere be explosive, the viewer or fireman lowers his lamp very slowly and cautiously until it has passed out of the explosive mixture, which usually occupies the upper part of the gallery of a mine, and travels in that position, notwithstanding the law of diffusion. There are many well authenticated cases of explosions through the gauze of the Davy lamp in a quiet atmosphere, and where the lamps, after the explosions, have been ascertained to be in good order.

A very ingenious instrument has recently been devised for the detection and quantitative estimation of the explosive gases by Mr. G. F. Ansell, of the Royal Mint. The instrument, which may be constructed in several different forms, is based upon the well known law in accordance with which gases gradually mix with one another through porous septa, and even through some materials which do not appear to possess any interstices through which the gases might pass.

If a tube blown out into a cup at one end, (Fig. 1,) and bent in the form of the letter U, be filled with mercury, so that the mercury stands in the cup, and the cup closed by a piece of porous tile cemented on by a resinous varnish, a very serviceable indicator is obtained. On bringing this instrument into an atmosphere containing a gas differing from that contained within the cup, perceptible diffusion takes place through the unglazed earthenware. If the cup be filled with air and the apparatus introduced into an atmosphere of hydrogen, the hydrogen will pass into the cup more rapidly than the air will pass out, according to the well known law that "gases diffuse into one another in the inverse proportion of the square roots of their specific gravities." The specific gravity of hydrogen being 1, that of air is 14·4. As the square root of 14·4 is 3·8, for every one part of air which diffuses out of the cup 3·8 parts of hydrogen will pass in through the porous tile. Thus the pressure on the mercury within the closed limb will exceed that on the the liquid in the open limb, and a corresponding elevation of the mercury in the open limb will result. When the maximum effect has been produced, the pressure within the cup will gradually force the

FIG

gas through the porous diaphragm until the mercury stands level in both limbs. At this point the gases within and without the apparatus possess the same composition, but any change of proportions in the external atmosphere is immediately indicated by the level of the mercury. If the instrument be removed into the air, the hydrogen within will immediately diffuse outward, and a rise of the mercury in the closed limb will result.

If the apparatus containing air be placed in an atmosphere of a gas of greater density than the air—as, for instance, carbonic acid—diffusion will take place, but the converse phenomena will be observed. The specific gravities of air and carbonic acid being in the proportions of 14·4 to 22, the diffusion will take place in the ratio of 4·7 to 3 8, *i. e.* for every 4 7 volumes of air which pass outwards, 3·8 of carbonic acid will pass inwards, so that the pressure on the mercury in the open limb will exceed that in the closed limb, and the mercury in the latter will rise; the alteration of level obviously being less than in the previous case, in which hydrogen was without a diaphragm. Of course, the theoretical elevation and depression of the mercury can in no case be observed, for, during the whole time that diffusion is going on, effusion takes place in consequence of the increased or diminished pressure of the apparatus. Mr. Ansell has constructed several pieces of apparatus on this principle. One (Fig. 1) consists simply of the U-tube with a scale graduated so as to indicate the per centage of mine gas present. In another form of the apparatus (Fig. 2) *a* is a piece of biscuitware cemented to a glass vessel (*b*), which at its lower end communicates with a U-tube containing mercury, on which, as it rises in the open limb, there floats a small weight, to which is fastened a cord passing over a pulley and counter-balanced on the opposite side, the rise and fall of the mercury causing the pulley to revolve and to indicate the alteration of pressure by the movement of a pointer on a dial (*c*). This is for use *only* on occasion of a sudden irruption of fire-damp.

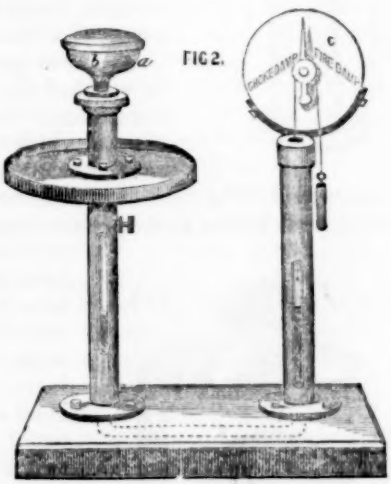


FIG 2.

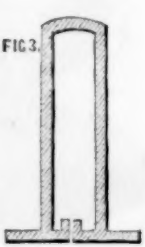


FIG 3.

Fig. 3 is a section of a porous battery cell which is used instead of the glass vessel (*b*) in Fig 2, but it does not give better results than those attained by the tile (*a*).

Another apparatus (Fig. 4) on the same principle has been con-

structed by enclosing a U-tube with a bulb containing mercury in an inverted porous battery cell. The edge of the cell is firmly cemented on to a piece of wood; a small metal weight floats on the surface of the mercury in the tube, and is attached to a piece of string, which passes over a pulley, and, by the alteration of the mercury level in the tube, moves an index, as in the previous form of the apparatus. On bringing the porous cell into a gas containing carburetted hydrogen, some of the gas diffuses into the cell, causing a rise of the mercury in the glass tube and a corresponding movement of the index.

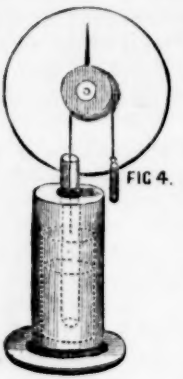


FIG 4.

All these modifications of the apparatus must be watched in order to obtain any information from them; but Mr. Ansell has constructed an alarum, which rings a bell if any quantity of gas SLOWLY ACCUMULATES round the indicator. The instrument, (Fig. 5,) consists of one of the thin india rubber balloons (*a*) so well known at the present time. One of these is placed on a piece of brass, which can be raised and lowered by a screw. The upper end of the balloon presses against a lever (*b*), which, when raised, liberates a train of clockwork at (*o*), and rings a bell (*e*). To increase the movement of the lever a band of linen is bound around the equator of the balloon in order to prevent lateral expansion and to concentrate all increase of volume in a polar direction. If this apparatus be placed in the gallery of a mine, the presence of or an increase in the quantity of mine gas will cause the expansion of the balloon, and consequent ringing of the alarum. The balloon remains in its expanded state until the composition of the atmosphere is altered.

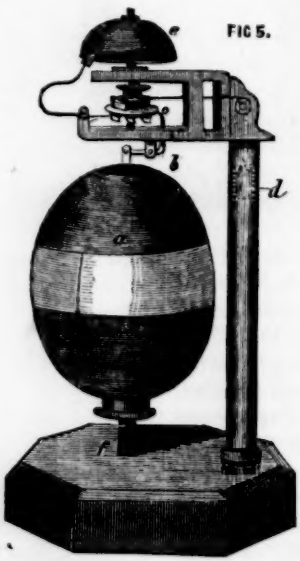


FIG 5.

Mr. Ansell has devised an instrument which, for elegance and utility, far surpasses all the others, as it admits of the determination of the quantity of mine gas present in a mixture. The apparatus consists of a small aneroid barometer, the case of which is made perfectly air-tight, but the interior of which may be placed in communication with the external air by opening a small screw fastened on the handle. The brass back of the barometer is replaced by a thin plate of porous earthenware, and may be covered with a brass cap or back placed on a hinge like that of a watch. Under ordinary circumstances the screw remains open, but when it is required to test the

gas in a mine, the screw is closed and the cap removed from the porous plate. Immediately diffusion takes place, and, the pressure increasing, causes a corresponding movement of the hand of the barometer. In about forty-five seconds the maximum effect is produced, when the position of the hand indicates, by means of a vernier, the per centage of mine gas present. If the apparatus be left for a sufficient time, the internal pressure forces the excess of gas through the porous plate, and the needle returns to the zero point. On subsequently allowing diffusion to take place into pure air, the index retrogades to the same extent (if the mixture does not contain more than 10 per cent. of mine gas or "fire-damp") to which it had previously advanced. This apparatus, which is not larger than an old-fashioned watch, will undoubtedly prove of great service to the mine overseer, as it can at any time be carried into the gallery of a mine. The per centage of gas is determined in less than a minute.

As is to be expected, the motion of the train of trucks running into or out from the pit, causes a variation of the pressure; therefore it is necessary to avoid such intervals in making observations by the instrument last described. It is well to mention that temperature need not be taken into account, for it is found that the temperature of the same part of a mine does not vary from year's end to year's end. The instruments denoted by Figs. 2, 4, and 5 are connected with telegraph arrangement, and these, as well as the aneroid barometer, have given full satisfaction to practical miners in several mines where they have been tried.

On some of the most Important Chemical Discoveries made within the last Two Years. By Dr. F. Crace Calvert, F. R. S., F. C. S.

II.

(Continued from page 262.)

From the London Journal of the Society of Arts, No. 673.

On the Discoveries in Chemistry applied to Arts and Manufactures.—One of the most curious and important applications which have lately been made of chemistry to manufactures is that of coal gas as a means of obtaining intense heats. In fact, heats have been secured which far exceed those previously obtained by the combustion of coals and other carbonaceous matters.

To understand how this result has been effected, it is necessary that I should say a few words on the combustion of coal gas. When coal gas is ignited, the oxygen of the atmosphere first combines with the hydrogen of the hydrocarbons, either gaseous or sufficiently volatile to assume a gaseous form, so as to produce water. Whilst a part of the carbon of these hydrocarbons combines with the oxygen to produce carbonic acid, the other portions of carbon float in the mass of ignited gaseous matters, and reach a sufficient temperature to radiate light in all directions. It follows, therefore, that the richer the coal gas is in hydrocarbons, into the composition of which enters a large proportion of carbon, the more brilliant will be the flame.

This is beautifully illustrated by an invention which I have the pleasure of showing you through the kindness of Rev. Mr. Bowditch, of Huddersfield, who has lent me one of the apparatuses which he has lately invented to increase the illuminating power of inferior coal gas, and which has been applied with success in the city of London, by its learned officer of health, Dr. Letheby. It consists in the introduction of carburetted hydrogens, rich in carbon, into the flame of ordinary coal gas, thus enhancing, in a marked degree, its illuminating power. This apparatus consists of a gas-tight metallic vessel, which holds the hydrocarbons, and which has an inlet connected with a gas supply and an outlet connected with the burner. The gas in its course passes over the surface of the hydrocarbons. Being above the flame, the vessel and its contents become heated, and part of the latter is converted into vapor, which the passing gas carries with it to the burners to enrich the flame.

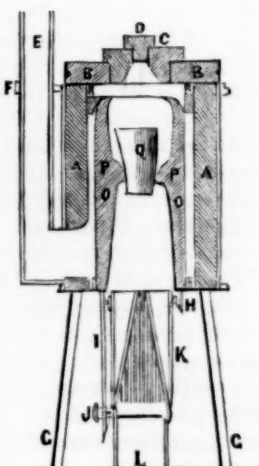
The following are the advantages which Mr. Bowditch's apparatus presents: Common coal gas, Ashburton flat flame, fish-tail, and bat-wing does not yield a light of 1·5 standard sperm candles per foot, though it yields the light of 2·4 candles per foot when burnt in a 15-hole Argand with a 7-inch chimney. By adding 31·5 grains of naphthalin vapor to each foot of this gas the light-giving value is raised to between seven and eight candles per foot, according to the constitution of the gas with which the vapor is burnt. Oils do not yield quite so high a result as naphthalin, but they afford from 4·5 to 5 times the light given by gas alone. To show the economy of gas, I may cite the following results, given to me by Mr. Bowditch: A gallon of oil, sold retail for 2s., is capable of producing, with 1000 feet of London gas, more light than is given by 4000 feet of gas, or 4s. 6d. gas and 2s. oil against 18s. gas alone. The hydrocarbon vessel requires charging about once in 14 to 16 days.

But let us now return to the production of intense heat by the combustion of coal gas. This is effected by burning gas with an excess of air, generally speaking, under pressure, so as to bring into contact in a given space of time a large quantity of gases, especially an excess of oxygen, with a view of rendering perfect combustion of coal gas. The first instance, to my knowledge, of the perfect combustion of coal gas as a commercial application, was its use in machines for singeing cotton and woolen fabrics, or for the purpose of removing from their surface all loose and useless fibres. One of the most perfect machines which I have yet examined for accomplishing this purpose has been lately introduced to the notice of manufacturers by Joshua Schofield & Sons, of Manchester. The great merit of their machine consists in the fact that by it they can vary either the intensity of the flame or its length, according to the pressure at which the gases in combustion are made to issue from the machine. In fact, they can adapt with such nicety the action of the machine to the nature of the fabrics they have to singe, that it can be applied to the finest fabric, such as cambrics, and to some of the heaviest materials in cotton, such as fustian.

The most remarkable example of the intense heat which can be

obtained by the combustion of gases was brought into notice a few years since by that distinguished chemist M. H. St. Clair-Deville, (the discoverer of aluminium,) by which he succeeded not only in melting several metals which, until his experiments, had resisted all other modes of effecting their fusion, but in melting in his laboratory as much as 25 lbs. of platinum, one of the most refractory metals known, and running it into one solid ingot. In 1862, the well known metallurgists, Messrs. Johnson & Matthey, invited to their works a large circle of the most scientific men of Europe, who were attending the Exhibition as jurors, to witness the fusion of 220 lbs. of platinum, and the running of it into one single solid ingot. This wonderful exploit in the production of heat was effected in a furnace similar in principle to that which had been devised by M. St. Clair-Deville, viz: in a furnace, the inner part of which was lined with blocks of quick lime, the only material found by M. Deville to be susceptible of resisting the intense heat which was produced by bringing at the upper part of the furnace a large jet of gas and air intimately mixed, and working under pressure. The flame, in passing from the upper part of the furnace and making its exit at the lower part, produced so great a heat as to melt the above stated quantity of platinum.

The observations of M. Deville soon brought into existence some extremely simple and handy furnaces to effect fusions and assays on a laboratory scale. Some of the best furnaces contrived for that purpose are due to Mr. J. J. Griffin, of Bunhill-row. The principal feature of his furnace is using as a generator for heat a large Bunsen burner, which consists of a hollow tube, at the bottom of which there is an inlet for coal gas, and at a certain height in the tube a number of openings through which the air rushes in to mingle with the gas; both air and gas issue at the top of the tube, and when ignited produced an intense heat. The flame so produced is made to play round a crucible containing the materials to be assayed, and which itself is surrounded by thick earthenware tiles, preventing the heat passing through the furnace from radiating itself in all directions, thus concentrating its action entirely on the little crucible placed in the centre. But the most perfect contrivance of the sort which has yet been brought to the notice of the public is one due to Mr. G. Gore, F.R.S. The following is the description of Mr. Gore's gas furnace: A is a cylinder of fire-clay, about 9 inches high and 6 inches diameter, open at both ends, and with a hole at the back part near the bottom, to lead into the chimney; it



is covered by a movable plate of fire-clay B, with a hole in its centre for the introduction of the crucible or of substances to be melted. This hole is closed by a perforated plug of fire-clay C, for access to the contents of the crucible; and that again is closed by another stopper of fire-clay D. E is a chimney of sheet iron, about 5 or 6 feet high, kept upright by a ring of iron F, attached to the top of the furnace. The fire-clay cylinder is enclosed in a sheet iron casing with a bottom of iron, to which are fixed three iron legs G. An iron tube H, with a prolongation I, supports, by means of the screw J, the burner K, and its tube L, which is open at both ends. Gas is supplied to the burner by means of the tap M, which has a small index N, attached to it for assistance in adjusting the gas. Inside the largest cylinder is another fire-clay cylinder or cupola O, with open ends, and with three projections of fire-clay P, for supporting the crucible Q; it is kept steady by means of three clay wedges R; S is an air-valve for closing the bottom of the tube L. The gas burner is a thin metal cylinder, deeply corrugated at its upper end, with the corrugations diminishing to nothing at its lower end, as shown in the engraving. The action of this furnace is as follows: Gas is admitted to the open tube L by the tap M; it there mixes with air to form a nearly combustible mixture, which ascends through the burner, and burns in the clay cylinder O, being supplied with the remainder of air necessary to combustion through the tube H to the outer surface of the flame by means of the spaces between the corrugations. The flame and products of combustion pass up through the cylinder O, and then downwards outside of it to the chimney, the point of greatest heat being at Q.

Mr. Gore states that one of his smallest furnaces, consuming 33 feet of coal gas per hour, is capable of melting 8 ounces of copper and 6 ounces of cast iron; that the next sized furnace, consuming about twice the quantity of gas, will melt 40 ounces of copper.

But the most important improvement which has been effected of late years in the production of intense heat by the combustion of the gases generated through the distillation of inferior coals, is that of Mr. C. W. Siemens, F.R.S., of Great George Street. The benefits which are conferred on manufacturers and the public by the furnaces devised by Mr. Siemens cannot be overrated. They are not only economical in their use, but as they enable the manufacturer to use an inferior class of fuel to generate the heat required, they must undeniably be of great advantage; and to the public in general they will be a great boon, as they do away with the nuisance attached to all manufacturing districts, in the dark black smoke escaping from chimneys, polluting the atmosphere, and rendering it so disagreeable to those who are compelled by their occupations to live within reach of its influence.

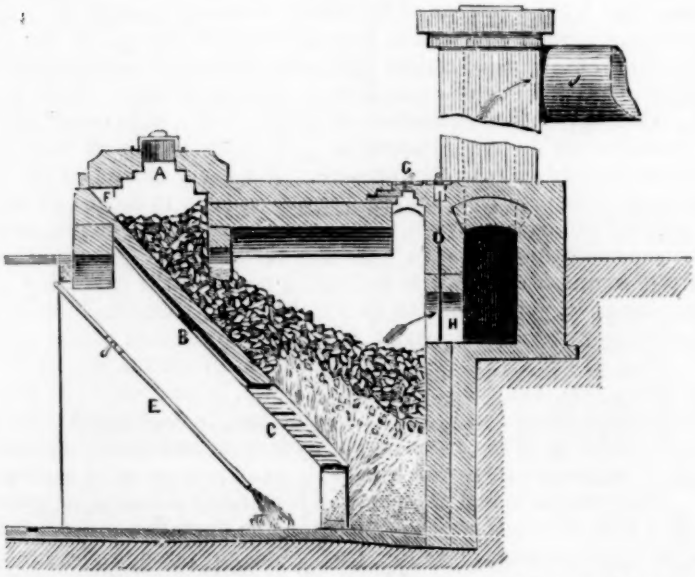
I may state, *en passant*, that the large amount of black smoke which floats in the atmosphere of Manchester, Sheffield, Birmingham, and other towns, is not only injurious by depriving those places of much light so beneficial to life and health, but is also a nuisance from the immense amount of soot and dirt with which it is accompanied. There cannot be a doubt that, owing to the imperfect combustion which the

products undergo in many of the furnaces belonging to manufacturers, and which is shown by the appearance of the smoke itself, the air is rendered more unwholesome than it would be if the products that escape had undergone perfect combustion, because volatile matters escape which are known to have a most destructive action on health and vegetation. The improved state of public squares in London—and of especially those which are on the banks of the Thames—can be witnessed by all who have observed their condition since the consumption of smoke has been made compulsory in London and its suburbs.

Mr. Siemens' furnaces, I am happy to say, are not in a state of mere experiment, but they have received the sanction of a great number of manufacturers, and especially of those who little expected that the necessary heat for their operations could be obtained without interfering with their manufacture, in the carrying out of which they thought the production of smoke could not be prevented. Thus we find M. Siemens' furnaces employed with great success and economy in glass-works, in potteries, and in iron forges, works which used to be a nuisance to their neighbors, by the large volumes of black smoke which they were constantly emitting from their chimneys.

Before describing M. Siemens' furnace, it is necessary that I should state that, in the ordinary furnaces, only about 25 per cent. of the

Fig. 1.



heating power of the fuel is rendered available in carrying out the manufacturing operations. This is due to imperfect combustion, and to the fact that only the heat of combustion exceeding that of the body treated is utilized; the remainder of the heat, in many instances by

far the greater proportion of the whole, being allowed to escape uselessly up the chimney.

I shall now give a description of one of Mr. Siemens' furnaces. The gas producer and furnace are quite distinct, and may be placed at any convenient distance from each other. The gas producer is shown in Fig. 1. The fuel is supplied at intervals of about two hours through the covered openings A, and descends gradually on the inclined plane B, which is set at an inclination to suit the kind of fuel used. The upper portion of the incline B is made solid, being formed of iron plates covered with fire-brick, but the lower portion C is an open grate formed of horizontal flat steps. The opening under the lower step is made larger than the others, to enable clinkers to be withdrawn. The small stoppered holes FF at the front and GG at the top of the producer are provided to allow of putting in an iron bar occasionally to break up the mass of fuel and detach clinkers from the side walls. Each producer is capable of converting daily about two tons of fuel into a combustible gas, which passes off through the opening H into the main gas flue leading to the furnaces.

The action of the gas producer in working is as follows: The fuel descending slowly on the incline plane B becomes heated and parts with its volatile constituents, the hydrocarbon gases, water, ammonia, and a small proportion of carbonic acid, which are the same as would be evolved from it in a gas retort. There now remains from 60 to 70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the current of air slowly entering through the grate C, producing regular combustion immediately upon the grate: but the carbonic acid (an incombustible gas) thus produced, having to pass slowly through a layer of incandescent fuel from two to three feet thick, takes up another equivalent of carbon, and is thus transformed into carbonic oxide (an inflammable gas) which passes off with the other combustible gases to the furnaces. For every cubic foot of carbonic oxide thus produced, taking the atmosphere to consist of one-fifth part by volume of oxygen and four-fifths of nitrogen, two cubic feet of incombustible nitrogen pass also through the grate, tending greatly to diminish the richness or heating power of the gas. Not all the carbonaceous portion of the fuel is, however, volatilized on such disadvantageous terms; for water is brought to the foot of the grate by the pipe E, which, absorbing the spare heat from the fire, is converted into steam, and each cubic foot of steam, in traversing the layer of from two to three feet of incandescent fuel, is decomposed into a mixture consisting of one cubic foot of hydrogen, and nearly an equal volume of carbonic oxide, with a variable small proportion of carbonic acid. Thus one cubic foot of steam yields as much inflammable gas as five cubic feet of atmospheric air; but the one operation is dependent upon the other, inasmuch as the passage of air through the fire is attended with the generation of heat, whereas the production of the water gases, as well as the evolution of the hydrocarbons, is carried on at the expense of heat. The generation of steam from the water, being dependent on the amount of heat in the fire, regulates itself

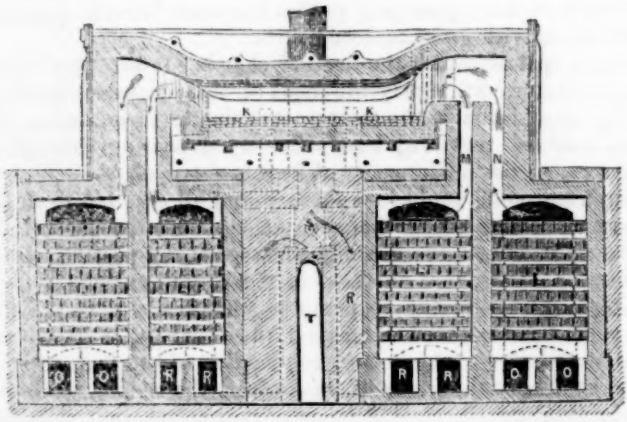
naturally to the requirements; and the total production of combustible gases varies with the admission of air, and since the admission of air into the grate depends in its turn upon the withdrawal of the gases evolved in the producer, the production of the combustible gases is entirely regulated by the demand for them.

The gas made in these producers has been frequently carefully analyzed, and the average constituents of 100 parts has been found as follows:

Carbonic acid,	4·1
Oxygen,	0·4
Carbonic oxide,	23·7
Carburetted hydrogen,	2·2
Hydrogen,	8·0
Nitrogen,	61·5
	99·9

The furnaces are applicable for all purposes where intense heat is required, such as for glass-houses, puddling, heating iron and steel, iron melting for foundry purposes, steel melting, muffles, and copper smelting. In all applications the furnaces are of the same construction in principle, the arrangements only varying with the different operations to be carried on in the heating chamber. The heating furnace has been selected for illustration in Fig. 2.

Fig. 2.



Underneath the heating chamber K are placed transversely the four regenerators L, L, L, L, which are chambers filled with fire-bricks built up with spaces between them. The regenerators work in pairs, the two under the right-hand end of the furnace communicating with that end of the heating chamber, while the other two communicate with the opposite end.

The gas passes from the main gas flue through the reversing valve S into the flues RR, at the bottom of one of the regenerators L, up through which it passes to the port M. Air is also admitted through a revers-

ing valve at the back of S, (not shown in the figure,) thence into the flues O O, up through the second regenerator L to the port N, where it meets with the gas, mingles with it, and produces an intense and uniform flame, which distributes itself all over the heating chamber K.

The products of combustion, together with the excess or waste heat of the furnace, instead of being passed, as in ordinary furnaces, up the stack, and either entirely thrown away or only partially utilized, are carried down into the other pair of regenerators, where they are deprived of their heat, and thence proceed through the reversing valves to the chimney by the flue T.

When one pair of regenerators has become considerably heated by the passage of the hot products of combustion for some time, and the opposite pair correspondingly cooled by the upward passage of the cold gas and air, the valves are reversed, and the currents of gas and air then pass upwards through the regenerators last heated, whereas the products of combustion pass through those opposite. The process of reversing is repeated at fixed intervals, generally every half-hour, so that two of the regenerators are always being cooled by the gas and air taking up the deposited heat and carrying it back to the furnace, and two always being heated by the passage of the hot products of combustion passing down to the chimney, and depositing their heat on their way there.

The flame in the heating chamber is uniform throughout, and perfectly free from all extraneous matter. Its chemical nature is also perfectly under command by means of gas and air regulating valves, (not shown in the engavings,) so that the most delicate operations can be carried on with great uniformity.

The gas and air reach the heating chamber (after passing through the regenerators) at nearly the heat of that chamber itself, and in burning, in addition to the temperature due to their mutual chemical action, is added that they have taken up in passing through the regenerators, so that an intensity of heat is obtained, which, unless moderated on purpose, would fuse furnace and all exposed to its action.

The products of combustion are so completely deprived of the heat they brought out of the heating chamber K, by passing among the regenerator bricks, that the heat in the chimney flue is seldom sufficient to singe wood; the economy is therefore due to the fact that little or no heat is thrown away up the chimney, as in the ordinary furnaces, and also to the perfect combustion of the fuel, which is evidenced by the total absence of smoke from the stack; whereas, in the common furnaces the combustion is so imperfect, that clouds of powdered carbon, in the form of smoke, envelope all manufacturing towns, and gases are allowed to escape with two-thirds of their heating power undeveloped.

The saving of fuel in these furnaces, as compared to the ordinary kind, ranges between 40 and 60 per cent. in weight, according to the fuel used. In many instances an additional saving can be made in the cost of the fuel by using inferior qualities, such as coal and coke dust, lignite, and peat.

The intensity of the heat, purity of the flame, and the absence of cutting drafts in the heating chamber, is of great advantage for all metallurgical operations, tending greatly to improve the quality of the produce, and occasioning a saving of about 5 per cent. in the waste of the metal treated in puddling and iron reheating furnaces, &c.

The peculiarities and advantages of these furnaces are, that gas fuel alone is employed, that perfect and entire combustion is obtained, and that the heat, which is usually allowed to escape up the chimney, is here stored up to be afterwards brought back to the furnaces.

Whilst on the question of the combustion of coals, and of smoke, allow me to draw your attention to a clever invention by Mr. Snook, of Manchester, which he calls an "Invigorator." The invention may briefly be described as an apparatus placed within the semicircle forming the upper portion of an ordinary register fire-grate, formed entirely of cast iron, and so constructed as to be readily applied to all existing grates known as of the register form. In experiments which have been made, it has been proved that, after lighting the fire, (the whole of the apparatus being closed so as to act as a blower,) a brisk, bright fire is produced in about four minutes. A large concave elliptical plate immediately over the grate bars, suspended on end pivots, is tilted over to an angle of about 70°, when it is seen that the back or concave portion of the plate, acts as a bright reflector, throwing out the heat rays into the room, instead of allowing them to pass up the chimney. Two horizontal plate doors, or louvres, above the reflector, are next opened, when the draft is found to be reduced to the smallest amount compatible with the continuance of combustion in the grate. The heat thrown out from the fire is considerable, and the fire itself forms a pleasant object to look at, having a warm, red glow, without either flame or smoke proceeding from it.

The next invention I wish to call your attention to is one, which, like that of Mr. Siemens', is calculated to render marked service to society. It is the production of motive power through the combustion of coal gas, and you will, I hope, appreciate the discovery due to Mr. Lenoir, if you will call back to memory the efforts which have been made for the last twenty or thirty years to generate power by employing the expansion which air or other gases undergo under the influence of heat as a substitute for steam—the long promised success and the unfortunate failures of Ericsson. What especially recommended the engines of M. Lenoir is their safety, for there is no danger of explosion; their cleanliness, for they require no fuel; their simplicity, which enable those who employ them to use them in any room, at any height, and at any spot where motive power may be required, for they have only to erect a little engine of one or two horse power, and whenever they require to use it, all they have to do is simply to bring into contact two poles of a battery, when the fluid so generated will traverse space, and convey motive power to the gas engine. Lastly, these engines are extremely economical in their working, for they consume only 70 feet of gas per horse power per hour; and assuming that 1000 feet of gas is worth 4s. 6d., the cost of working an engine of one

horse power will be about 4d. per hour. M. Lenoir's engine is very similar to the ordinary steam engine, having a cylinder, piston, crank shaft, and fly wheel. The following proportions of gas are admitted in the cylinder: One volume of coal gas mixed with twelve volumes of atmospheric air. This mixture is ignited by the electrical spark from a battery connected by wires at each end of the cylinder. The connexion being made and broken by the rotatory action of the crank shank, the expansive force necessary to move the piston of the engine is produced by the ignition of the gas, which not only produces steam and carbonic acid by their combustion, but by the heat generated increases their volume to a sufficient extent to force the piston to travel backwards and forwards, thus producing motion. The engine once fixed, the battery charged, and the gas turned on, it is ready for action, and as soon as the work required is completed, the gas is shut off, the engine stops, and the expense ceases.

The facility for employing Lenoir's engine in countries where coal is not easily attainable has been increased by substituting for coal gas a mixture of oxide of carbon and hydrogen, which can easily be procured on a commercial scale at a small cost by passing steam over heated charcoal, the water being decomposed, its hydrogen being liberated, and its oxygen combining with the carbon itself produces oxide of carbon, and the mixture of these gases is a cheap and good substitute for coal gas. Consequently, M. Lenoir's engines can be employed with great advantage in our British colonies and in South America.

(To be continued.)

For the Journal of the Franklin Institute.

Fire in a Cotton Mill from Electricity. By JAMES B. FRANCIS, C.E.

On the 21st of March last, at about 8·30 A. M., the overseer of the spinning room in the Appleton Mills in this city noticed a smell of fire, and, in the course of five or eight minutes, discovered it on the upper side of a timber, in a belt box in the story below that of which he has charge. It had made but little progress and was immediately extinguished. My attention was called to it about half an hour after the fire was extinguished.

The belt box is an inclosure at the end of the No. 2 Mill, in which run the main belts, carrying power from the main shaft in the basement to the stories above. Three sides of it consist of a light wooden frame covered with boards, the fourth side is formed by the end wall of the mill. It is of different dimensions in the different stories; in the story in which the fire occurred, called the weaving room, it occupies about 7 feet lengthwise of the mill, and about 19½ feet crosswise. Two small water pipes, carrying off condensed water from steam pipes, pass through the belt box, maintaining it usually at a temperature between 80° and 90° Fahr. In the room outside of the belt box, the temperature at this season is usually between 70° and 80°.

I found the timber which had been on fire to be of white pine, about 7¼ inches square, having one end built into the brick wall, and the other end framed into one of the main floor beams; it lays horizontally and parallel to the face of a leather belt, 19½ inches wide. This belt is driven by a drum 11 feet in diameter, having iron arms and wooden lagging, and making 92 revolutions per minute; consequently, the belt moves at the rate of 3179 feet per minute. The amount of power transmitted by this belt is estimated at 175 horse power, corresponding to a tension of the tight side of the belt of not less than $\frac{175 \times 33{,}000}{3179} = 1817$ pounds. The pulley driven by the belt is 6 feet in diameter and is entirely of iron; the peripheries of both drum and pulley are covered with leather. The belt is made of two thicknesses of leather cemented together, and is about three-eighths of an inch thick; it was slightly greased on the inside, seven or eight weeks before the fire, with a mixture of tallow and neats-foot oil.

The part of the belt near the timber was the slack side, running upwards. nearly vertically, and at the nearest point was about 8 inches from the timber, and when I first saw it, a constant stream of sparks was passing between the belt and the corner of the timber which had been on fire. The charred wood indicated that about 6 inches of the corner had been on fire, and that it had extended about an inch in width on the top of the timber, and about half an inch in width on the side nearest the bolt; neither the top nor side of the timber have been painted.

Opposite the middle of the charred surface, and nearly opposite the middle of the belt, and about 2½ inches from the charred corner, an iron bolt, three-quarters of an inch in diameter, passes vertically through the timber, having a nut on the top, and the lower end connected with a chain, supporting the iron frame of a binder pulley to another belt, driven by the same drum. Whenever I have tried it, a small spark could be drawn by the finger from any part of this iron work.

As stated above, at my first examination, sparks were observed passing between the belt and the corner of the timber; the next day I observed that they were passing between the belt and the top of the bolt and nut, and not, so far as could be seen, to the corner of the timber. At my first examination the timber had just been wetted for the purpose of extinguishing the fire; the next day, on wetting it again, the sparks were observed to pass between the belt and corner of the timber, as at my first examination. I have frequently examined it since, and, when the belt was moving, have always found sparks passing between the belt and the top of the bolt and nut.

The electrical excitement in the Appleton Mills at the time of the fire was unusually great, as was shown by the brilliance and length of the sparks, and the force of the shocks to the body on coming near some of the belts. I have not observed sparks passing between the belt and timber when the latter was dry, as it undoubtedly was, when the fire originated. So far as I have observed, however, the electrical

excitement has not since been so great as it was on the day of the fire, and I can find no other probable cause for the fire, and the conclusion is irresistable that it was caused by electricity.

It is not unfrequent to find in the belt boxes of a mill an accumulation of dust and flyings of cotton or wool, covering everything not in rapid motion to a sensible depth. In this case the belt box was very clean, to which fact, perhaps, may be attributed the slow progress of the fire and the detection of its cause.

Electrical excitement, manifested by sparks, shocks, and the symmetrical arrangement of the fibres of cotton and wool, is so common in our cotton and woolen mills as to excite no remark; it is, however, very different at different times. It is frequently used to light gas; a person standing on the wooden floor, and presenting one finger to a belt from which he can draw sparks, and another finger to the gas as it issues from a metal burner, the gas is instantly lighted. When the electrical excitement is strong, the same thing can be done at a considerable distance by several persons holding each others' hands. It has never been observed here before, that any other substance than gas could be thus ignited. Since this fire, however, the agent of the Appleton Company has succeeded in igniting tinder, by the sparks passing between the belt and the top of the bolt, and I have since done the same thing.

Many fires have occurred in our cotton mills which could not be accounted for at the time; ample means are provided for extinguishing fire, if promptly applied, which they are likely to be when the machinery is in operation, when, of course, the work-people are at hand. So far as I have observed, electrical phenomena are exhibited in the mills only when the machinery or shafting is in motion. By the light of the late fire at the Appleton Mills, it appears probable that many other fires, which were totally inexplicable at the time of their occurrence, may be attributed to this cause.

The exhibition of electricity in our mills is usually greatest in very cold weather, when the atmosphere contains the least moisture. At the time of the fire above described, the weather was quite different, being mild and cloudy, with a slight drizzle of rain falling. About 3 inches of snow fell during the preceding night. At 6·30 A. M., when the mill started, the temperature out of doors was 30°, at 2 P. M., 40°.

Lowell, Mass., April 3, 1866.

Photographing on Copper.

A M. Mialaret-Becknell writes from Saint-Jean Baptiste, Louisiana, to the *Cosmos* of Paris describing a method of photographing on copper and etching the photograph produced. The method is, in brief, the following, and it may be worth while for amateurs to experiment with;

Take a perfectly smooth and thoroughly clean plate of copper, dry it perfectly and immerse it in a bath of—

Sulphate of copper, ...	125 grains.
Sea-salt, ...	75 "
Water.	2 ounces.

Acidify the bath with a few drops of any acid to prevent the formation of a pellicule which would stain the plate. After an immersion of from thirty to sixty seconds (or more, if desirable) the plate is freely washed with water and completely dried with an old piece of linen soft enough not to scratch the metal, then rubbed smartly with soft flannel until it presents a perfect polish. In this condition the plate may vary in tone from a vivid red to a violet. These operations may be performed in diffused light, but too much light should be avoided. Place the plate in a frame behind an engraving or a glass negative and expose to the sun. With a good light it will take from five to ten minutes. After this the plate may be preserved for some days without alteration, provided the weather be dry and it be not exposed to a strong light; but as it is very hygrometric it had better be fixed immediately upon withdrawing it from the frame. This is done by plunging it into hyposulphite of soda containing a few grains of chloride of silver. In a few seconds the red tones of the plate whiten, the shadows take a violet tone, which finally turn to black. Precisely at this instant the plate must be withdrawn from the bath and agitated rapidly in a basin of pure water. After which the black deposit which forms the shadows must be removed, unless you prefer to let it remain. In this case wash in much water and dry rapidly over an alcohol lamp with feeble flame. As the shadows are formed of a powder which the slightest rubbing removes, they can be preserved by a transparent varnish.

But if the plate is to be engraved chemically, the black powder must be removed as indicated above, the plate washed under a strong jet of water, and plunged without drying into the liquid selected as a mordant. On this point I have nothing definite to say. All substances which act violently and evolve gas must be avoided. The following formula has sometimes succeeded:

Nitric acid, ...	1 part.
Bichromate of potassa, (saturated solution,) .	2 parts.
Water, ...	3 "

In this formula the nitric may be replaced by sulphuric acid. I varnish the back and edges of the plate and plunge it into enough liquid to cover it. When the liquid assumes a blue tint I add more without touching the plate, and I prolong the action one or two days, according to the temperature. I have tried iodine in combination with the bichromate or nitric acid; in this case it is better not to remove the shadows. With the first formula the engraving is in relief, that is, the plate is attacked only in those parts which are covered with silver; by galvanism a plate is produced in which the shadows are depressed. Iodine and other agents which attack the copper and leave the silver have, therefore, advantages, but the iodine is much slower in its operation. Or the plate may be engraved galvanically by attaching it to the positive pole of the pile and immersing it in a very acid solution of sulphate of copper. The plate must be laid horizontally

and the copper plate which serves as the negative electrode must be above it, otherwise the coating of silver will become detached. Or it may be attached to the negative pole, in which case the shadows will be coated with copper.

New Ice Machine.

From the Practical Mechanics' Journal, December, 1865.

A machine for the production of ice on a large scale has lately been tried at Paris with great success. Its peculiar feature is that, unlike all the machines whose action depends on the circulation of ether or ammonia, it requires no pump whatever. Its effect is produced by means of heat and the circulation of the vapor of amylic ether, (oxide of amyle.) The latter is obtained, as usual, by the action of sulphuric acid on amylic alcohol, or that derived from potatoes; and it is liquefied by transmission, at a pressure of from five to seven atmospheres, into a reservoir placed under the cylinder. After having returned to the state of gas and formed ice, when a cock is opened, it passes from this reservoir into the spiral ducts which surround the quadrangular reservoirs, which are filled with the water that is to be congealed, and are immersed in a solution of salt that will not freeze. After the ether has been vaporized in the spirals, it passes successively into three large cylinders containing sulphuric acid, by which it is dissolved. One portion of the ether, being contained in the concentrated solution, is ready to yield up vapor under the action of the heat afforded by the circulation of superheated steam. A second vessel is ready to absorb the ether vapor. The third is in a state of rest, and ready to give up its ether. A machine of this kind, calculated to produce about a quarter of a ton (200 kilos.) of ice per hour, has been constructed for the concentration of sea-water, for the purpose of extracting its soda, potash, and other salts. The application of refrigeration to the separation of substances held in solution has been attended with the best and most economic results, and is becoming more general every day. It has been used even in the separation of sugar from syrup. Water, in freezing, completely separates from anything which it holds in solution.

Nitro-glycerine for Blasting.

From the London Journal of the Society of Arts, No. 689.

The *Berg-und Hüttenmännische Zeitung* states, that, among other disadvantages of Nobel's nitro-glycerine, is the fact that it freezes at a temperature very probably above 92° Fahr. It is said that even at a temperature of 43° to 46° Fahr. the oil solidifies to an icy mass, which mere friction will cause to explode. It is probable, however, that the freezing point of the oil lies somewhat lower than is here stated, though as yet no exact determination of the freezing point of the oil has been

made. A newspaper from Hirschberg, in Silesia, gives a sad account of an accident, caused by the frozen oil exploding by friction. Nitro-glycerine is there being used in making a railway tunnel. It was kept in glass vessels, packed in straw, and placed in baskets, each vessel containing one-fourth to one-eighth of a hundred-weight of the oil. For several days the oil had been frozen. It was carefully handled, and pieces were separated by means of a piece of wood, and put into the bore-holes, and it was found that the frozen nitro-glycerine exploded quite as well as the fluid. One day an overseer at the shaft hit upon the unlucky idea of breaking into pieces with a pick a seven or eight-pound lump of the frozen glycerine. The blow caused the mass to explode, and the unfortunate man was blown up into the air, and fell back into the shaft, some forty or fifty feet deep, whilst two workmen, who were making cartridges a short distance from him, luckily escaped with slight injuries.

Simple Method of Preventing Boiler Incrustations.

From the London Chemical News, No. 317.

In a manufactory at Lorenzchacht they use water holding a little clay in suspension, and, after three months' work, find on the sides of the boiler only a little mud, which is easily scraped off. This mud is nothing more than the clay itself, which prevents the deposit of crust mechanically by keeping the particles of deposited matters apart.

The New Atlantic Telegraph Scheme.

From the London Civil Engineer and Architect's Journal, March, 1866.

On the 2d ultimo a meeting was held, at the London Tavern, of gentlemen interested in the question of laying the most efficient and economical lines of telegraphic communication between England and America and the Colonies, and the advantages to be derived from the adoption of Macintosh's system of constructing deep sea cables. The Earl of Shrewsbury presided.

Mr. Macintosh proceed to explain the advantages of laying a cable direct from England to the United States, *via* Falmouth and Cape Cod. The proposed route was divided by shallow water into four parts—Chaucer's Bank, Milne Bank, and Newfoundland Bank, so that in case of accident the cable should be readily recovered for repairs. The peculiarities of the Macintosh system of constructing telegraph cables consisted in using a new insulating material of superior efficacy to any known substance, which enables a rate of 80 per cent. more signalling power to be obtained than in the case of the late Atlantic cable. All external iron wire sheathing, whether alone or in combination with tarred hemp, as in the late Atlantic cable, and all

steel wire spiralled round the conductor, would be dispensed with, and thus one great source of danger and expense was avoided. The mechanical strength requisite for the cable was obtained for the materials employed in insulating its conductor, which material was applied in numerous coatings or films, under tension, and a pressure of several tons, so that all superfluous weight was avoided, and such an excess of strength was obtained that the cable would sustain twenty miles of its length in water; and three cables could be constructed by Macintosh's system for the price of one such as it was lately attempted to lay across the Atlantic. The conductor of Macintosh's cable consisted of a series of fine copper wires, laid longitudinally, and held together by the insulating material; the cable was constructed in one continuous length, without welds or joints, and, when finished, was at once the smallest, lightest, least expensive, and most effective submarine telegraph known; and, moreover, it could be laid with a decreased risk of failure by the adoption of Mr. Macintosh's compensation apparatus for paying out cables with an uniform tension in all weathers. The soundings of the proposed route were very favorable, the cable could be made very inexpensively, and its greatest safety would be in getting into the deepest possible water. He had not brought forward his project on the wreck of the Atlantic Company's scheme; for it was submitted to the Leeds meeting of the British Association, nearly eight years ago, in the section over which Mr. Fairbairn presided, and his opinion was that all deep sea lines should be made with a conductor and insulator alone. The result of experiments already made shows the weight and capabilities of equal lengths of the late Atlantic cable, and of Macintosh's cable in the following manner:

	New Atlantic.	Macintosh's.
Conductivity in lbs. copper,	300 lbs.	300 lbs.
Weight of insulating material,	400 lbs.	400 lbs.
Inductive resistance in lbs. of gutta percha,	400 lbs.	2000 lbs.
Diameter of cable,	1 1/2 inch.	1/4 inch.
Weight per nautical mile in air,	35 3/4 cwt.	6 cwt. 28 lbs.
Weight per nautical mile in water,	14 cwt.	1 3/4 cwt.
Specific gravity,	2·1	1·3
Breaking weight,	11,000 fathoms.	17,000 fathoms.
Weight of 2300 nautical miles of cable,	4111 tons.	718 tons.

From the above statement it will be seen that 2000 lbs. of gutta percha are only equal, for purposes of insulation, to 400 lbs. of Macintosh's compound, and the respective cost of the materials per pound is at least three to one in favor of the compound.

Mr. Macintosh said he could lay his cable down for £100 per mile, and he had made that offer to the Atlantic Company. If they persisted in their old course he had no doubt that another line would be laid down long before their line could be completed.

Captain Selwyn wished to know what sort of cable could be constructed for £100 per mile, and what would be the rate of speed? Would the cable be of the same length and with the same speed, or of greater length with the same speed?

Mr. Macintosh said the cost of the line to Newfoundland would be £100,000, and, with the same sized conductor, he could get at least 80 per cent. more signal power.

Captain Selwyn regarded with interest the development of a new material of so much promise. He believed that the statements of the inventor as to the advantage of the material could be proved, and he considered it was as applicable to underground electric telegraph lines as submarine cables. The route proposed by Mr. Macintosh was one in which there was no deep water for any great length. The distance to the first sand-bank was 900 miles, the next distance was 500, then came another 500, and then one of 430. In no case was the depth more than from 100 to 200 fathoms, so that the cable might be easily recovered if broken, and the risk to the shareholders was consequently diminished under any circumstances to 900 miles, which was the greatest loss it could incur. The Northern route had also the advantage of being divided into sections, but it had the disadvantage of having nine shore ends, and all electricians knew that shore ends were the great difficulty.

Captain Davis, as a nautical man acquainted with laying deep sea cables, would prefer taking the responsibility of laying three of Mr. Macintosh's cables to one of the Atlantic Telegraph Company's cables. He remarked that, as there was nothing to pay for concession, the advisability of forming a company to carry out the scheme was well worthy of consideration.

The chairman inquired whether Mr. Macintosh had any certificates as to the electrical condition of the cable? Mr. Macintosh replied that he had those Mr. Desmond Fitzgerald and Prof. Miller.

After a lengthened discussion, relative to the various materials employed for insulation, Mr. Harry Lobb moved the following resolution: "That, having heard Mr. Macintosh's statement, this meeting expresses confidence in the advantages of his system, and of its applicability as a means of direct telegraphic communication with America and the Colonies."

Captain Symonds seconded the resolution, which was carried unanimously; and it was agreed that another meeting should be held for the purpose of further considering the matter.

Incrustation of Boilers.

We accidentally omitted to notice at the proper time the receipt of a very interesting report by Prof. Chandler of the School of Mines, New York, "On the Water used for Locomotives on the New York Central Railroad and on Boiler Incrustations." The report contains carefully elaborated analyses of waters from seventeen different sources, and the summary of this part is made in the following excellently arranged table:

Composition of Waters now supplied to Locomotives.

Stations.	Corroding Constituents.						Incrusting Constituents.						Incrustation Preventives.		Organic Matter.	Total.
	Chloride of Potassium.	Chloride of Sodium.	Chloride of Mag'sium.	Sulphate of Potass.	Sulphate of Soda.	Sum.	Sulphate of Lime.	Carbonate of Lime.	Carbonate of Mag'sia.	Oxide of Iron.	Silica.	Sum.	Carbonate of Potassa.	Carbonate of Soda.		
Syracuse, Onondaga Creek,	0·32	2·14			0·98	3·44	10·68	7·25	4·31	0·06	0 28	22·58			0·34	26·36
" Hydrant,	0 24			0·07	0·07	0 38	16·71	6·84	3·69	0·06	0·25	27·55			trace	27·98
Warner's,	1·91			1·81		3·72		7·17	3 63	0·11	0 37	11·28	2·17	6·09	0·37	23 63
Memphis,	0·29	0·26			0·36	0·91	10·12	6·75	4 41	0·09	0·31	21·68			0·18	22 77
Jordan,	0·33	0 76			0 62	1·71	4·02	5·03	2·30	0·03	0·09	11·47			0·06	13 24
Port Byron,	0 39			0·32	0·37	1·08	0·01	5·43	1·57	trace.	0·16	7·17			1·28	9·53
Savannah,	0·59			0·07	0 69	1·35		11·93	5·04	0·10	0·56	17·63			1·52	20·50
Clyde, Spring,	0·14			0·18	0·45	0·77		9 66	4·40	trace.	0·58	14·64			2·16	17·58
" River,	0·52	0·37			1·21	2 10	4·40	6 07	3·03	trace.	0·80	14 30			1·88	18·28
Lyons,	0 29			0·03	0·71	1 03	3·17	4·38	3·34	trace.	0·18	11 07			1·00	13·10
Newark,	0 47	0·38			0 32	1·17	3·19	9 15	6 01	0·08	0 30	18 73			2·16	22·07
Palmyra,	0·76				0·67	1·43	18·81	8·41	5 98	0 02	0·17	33·39			1·46	36·28
Macedon Swamp,	0·14			0·18	0 39	0·71	0·14	7·68	2·23	trace.	0·48	10·53			0·80	12·04
Fairport,	0·34	0·69	2·16			3·19	8·72	5·07	1·03	0·01	0 20	15·06			1·14	19·39
Rochester, North Street Well,	0·96	4·82	1·53			7·31	6·46	16 92	8 88	0·10	0·90	33 26			1·60	42·17
" Genesee River,	0·28	0 05			0 85	1·18	3·16	4 64	2·06	0·09	0·90	10 85			1·64	13·67
" Canal, Round House,	0·33	0·17			0·61	1 11	2·16	4·69	1·81	0·05	0·18	8 80			1·24	11·15
Average,	0 49	0·57	0·22	0 16	0·49	1·93	5·39	7·47	3·75	0·05	0·39	17·05	0·13	0·36	1·10	20·57

The numbers represent grains per gallon of 231 cubic inches.

The numbers represent grains per gallon of 231 cubic inches.

This part of the report is followed by a very interesting analysis of the incrustations, of which the following is the summary:

Analyses of Boiler Incrustations.§

Source.	Structure.	Thickness.	Sulphate of Lime.	Carbonate of Lime.	Basic Carbonate of Magnesia.	Oxide of Iron and Alumina.	Water.	Organic Matter.	Silica.	Total.	—
1. Stationary engine, boiler shop. Syracuse: hydrant water,	Compact and crystalline.	$\frac{3}{16}$ths inch.	74·07	14·78	9·19	0·08	1·14	undet.	0·65	99 91	Fair average representatives of the usual incrustations.
2. *Stationary engine, machine shop. Rochester: canal water 10 mos., well water 2 mos.,	"	2 inches.	71·37			26·87‖			1·76	100·00	
3. Locomotive No. 211. Freight, both roads. Syracuse,	"	$\frac{1}{32}$d inch.	62·86	12·62	18·95	0·92	1·28	undet.	2·60	99·23	
4. Locomotive: surround'g brace,	"	$\frac{1}{4}$th to $\frac{1}{2}$d in.	53·05			42·16‖			4·79	100 00	
5. Locomotive No. 127. Freight, both roads. Syracuse,	"	$\frac{1}{32}$d inch.	46·83			47·85‖			5·32	100·00	
6. Locomotive No. 202. Freight, both roads. Syracuse,	"	$\frac{1}{4}$th inch.	30·80	26·93	31·17	1·08	2·44	undet.	7·75	100·17	
Average,	. . . . .	. . . . .	56·49	18·11	19·77	0·69	1·62	undet.	3·81	. . .	. . . .
7. †Stationary engine, Niagara Falls: river water,	Friable and granular.	2 inches.	4·95	86·25	2·61	1·03	0·63	undet.	2·07	97·54	Exceptional incrustations, the only ones of their kind.
8. ‡Stationary engine, Townsend's Furnace, Albany,	"	1¼ inches.	0·88	93·10	2·84¶	0 36	0·15	1·96	0·62	100·00	
9. Locomotive No. 122. Rochester to Buffalo,	Powder.		4·81			92·27‖			2·92	100 00	
10. Stationary engine. Barhydt & Greenhalgh, Schenectady,	"		30·07			61·69‖			8·24	100·00	

* A mass weighing 21 ounces, which had apparently filled the space between three tubes.
† A mass weighing 14 ounces, evidently detached from a tube.
‡ " " 16 " " " " " "

§ For method of Analysis see Appendix.
‖ This number includes those belonging to the two preceding and the two following columns, as obtained by difference.

And the incrustations are classified as follows:

1. Hard, compact, and crystalline, formed of numerous thin layers, and consisting of from 30 to 75 per cent. of sulphate of lime, associated with carbonate of lime, basic carbonate of magnesia, ($2\,Mg\,O, C\,O_2$,) etc., (Analyses 1 to 6.)

With a single exception all the locomotive incrustations were of this character, as were also most of those from stationary boilers. The incrustations from marine boilers belong to this class, consisting almost entirely of sulphate of lime.

2. Loose and friable, not at all crystalline; in thick masses, not in well-defined layers, composed chiefly of carbonate of lime, (Analyses 7 and 8.) Only two specimens of this variety were met with, both from stationary boilers. They are evidently deposited from water containing very little sulphate of lime.

3. Consisting of a fine powder or mud. Noticed in only two instances; in one case in a locomotive, in the other in a stationary boiler. In composition the two specimens differ; one consisting chiefly of carbonate of lime and magnesia, the other containing 30 per cent. of sulphate of lime, (Analyses 9 and 10.)

A dissertation on the formation of incrustations and the various methods of prevention follows, in reference to which the following analysis of water from boilers using different methods of prevention is interesting, but would be much more so had an experiment been instituted using the same water in each boiler.

	1. No. 101.	2. No. 106.	3. No. 113.	4. Stationary, Machine shop, Syracuse.
Distance run, . .	700 miles.	416 miles.	416 miles.	
Road, ...	direct.	Auburn.	Auburn.	
Preventive used, .	bran.	bran, 2 buckets.	nothing.	potatoes, one peck.
Reaction, . . .	neutral.	neutral.	neutral.	alkaline.
Sulphate of lime, .	17·88 grs.*	9·53 grs.*	39·89 grs.	49·82 grs.*
Carbonates of lime and magnesia, . .	trace.	trace.	trace.	trace.
Chlorides, etc., . .	56·76 grs.	19·38 grs.	52·95 grs.	37·42 grs.
Organic matter, . .	9·33 "	8·86 "	13·99 "	12·59 "
Nitrates, . . .	trace.		trace.	faint trace.
Total, per gallon, .	83·97 grs.	37·77 grs.	106·83 grs.	99·83 grs.

The following are the practical conclusions of the report:

"In conclusion, I would advise—

1. The use of the purest waters that can be obtained; rain water, wherever possible.

2. Frequent use of the blow-off cock.

3. That the boilers never be emptied while there is fire enough to harden the deposits.

4. Frequent washing out.

* These figures are probably too high, as they are calculated from the sulphuric acid, a portion of which probably exists in the form of alkaline sulphates.

5. Experiments on the efficacy of zinc, lime water, carbonate of soda, carbonate of baryta, chloride of ammonium, some substance containing tannic acid, linseed meal, and the electro-magnetic inductor."

On the Specific Gravity of Mercury. By BALFOUR STEWART, M. A., LL. D., F. R. S.

From the London Chemical News, No. 326.

Some time since, in connexion with a research on the fusing point of mercury, several observations were made at Kew of the specific gravity of this fluid. A specific-gravity bottle was used for this purpose, and it was washed, in the first place, with sulphuric acid; secondly, with distilled water; and thirdly, with alcohol; when this was done it was found to contain mercury without any air-specks or any diminution of that metallic lustre which pure mercury exhibits when in contact with a vessel of clean glass. Three different specimens of pure mercury were used, and were separately weighed in the specific-gravity bottle at 62° Fahr. The following results were obtained:

	Weighed in Air. Grains.
Mercury from the cistern of the old Kew standard barometer, filling the bottle, weighed at 62° Fahr., ...	13591·36
Mercury from the cistern of the new Kew standard barometer, weighed at 62° Fahr., ...	13591·66
Mercury used in experiments with air thermometer weighed at 62° Fahr., ...	13591·96

The mean of these will be 13591·66 grains. It was found that the specific-gravity bottle had an internal volume equal very nearly to 4 cubic inches, and assuming that a cubic inch of air weighs 0·31 grains, then the air displaced by the liquid filling the bottle would weigh 1·24 grains. In like manner the air displaced by the Kew standard weights (specific gravity 8·2) would have the volume of 6·6 cubic inches, and would weigh 2·04 grains. From these premises we find that the real weight of the mercury *in vacuo* would have been 13590·86 grains. Again, the amount of water which the same bottle held at 62° Fahr. weighed in air 1000·52 grains. Here the air displaced by the bottle is, as before, 1·24 grains, while that displaced by the weights is only 0·15 grain. From this we find that the real weight of water filling the bottle at 62° Fahr. would be *in vacuo* 1001·62 grains. We have thus

True weight of mercury filling the bottle at 62° Fahr. = 13590·82 grains.
True weight of the same volume of water at 62° Fahr. = 1001·62 "

And hence the specific gravity of mercury at 62° Fahr., as compared with water at the same temperature, will be 13·569 nearly. Again, if we assume the correctness of Regnault's table of the absolute dilatation of mercury, and also that of Despretz's table of the absolute dilatation of water, we shall find that the weight at 32° Fahr. of a volume of mercury weighing 13590·86 grains at 62° Fahr. will be

$$13590{\cdot}86 \times 1{\cdot}00298 = 13631{\cdot}361 \text{ grains.}$$

Also, the volume at 4° Cent., or 39·2° Fahr., of a volume of water weighing at 62° Fahr. 1001·62 grains will be

$$1001{\cdot}61 \times 1{\cdot}0011437 = 1002{\cdot}766 \text{ grains.}$$

Hence the specific gravity of mercury, according to the French method of determining it, will be

$$\frac{13631{\cdot}361}{1002{\cdot}766} = 13{\cdot}594.$$

A determination by Regnault gives 13·596. These two results agree very nearly with one another; and this agreement tends, not only to verify the correctness of Regnault's determination, but to show that Regnault's table of the dilatation of mercury and Despretz's table of the dilatation of water agree together; a remark that had been previously made by Dr. Matthiessen in a paper which he recently presented to the Society.

Proc. Royal Society.

M. Athanase Dupré calculates, for the Academy of Sciences of Paris, that a cube of water, having a side equal to one thousandth of a millimetre, (or about six one hundred billionths of a cubic inch,) contains more than 125,000,000,000,000,000 molecules of that valuable compound. If any one doubts this conclusion let him show it to be false by a fair count.

M. Simonin reports that the climate of San Francisco (to which he or the printers of the *Comptes Rendus* of the French Academy of Sciences assign the latitude of 27° 40′) is colder in summer than in winter; and that the coldest period of the twenty four hours is from noon until three o'clock. Whether this is also the darkest portion of the twenty-four hours he does not state.

Preservation of Vinegar.

From the London Chemical News.

It was an observation made by Scheele, but the fact has recently been published as a new discovery, that ordinary brown vinegar will keep bright and clear for any length of time if heated to the boiling point for a few minutes.

FRANKLIN INSTITUTE

Proceedings of the Stated Monthly Meeting, April 18th, 1866.

The meeting was called to order with the President, William Sellers, in the chair.

The minutes of the last meeting were read and approved. The minutes of the Board of Managers were reported.

At the meeting of the Board of Managers, held on the 11th inst., donations to the library were received from the Royal Society, the Royal Institution, the Royal Geographical Society, the Chemical Society, the Zoological Society, the Institute of Actuaries, and the Society of Arts, London, England; the Royal Irish Academy and Robert McDonnell, Esq., Dublin, Ireland; La Société d'Encouragement pour l'Industrie Nationale, Paris, and la Société Industrielle de Mülhouse, France; the K. K. Geologischen Reischsanstalt, the Osterreichischen Ingenieur-Vereins, Vienna, Austria; the Canadian Institute of Toronto, Canada; Prof. A. D. Bache, the U. S. Survey, Dr. Charles M Wetherell, and Frederick Emmerick, Esq., Washington, D.C.; Alfred P. Boller, Esq., City of New York; and from Profs. John F. Frazer and John C. Cresson, of Philadelphia.

In compliance with the Report of the Committee on Science and the Arts, the Board awarded to Mr. Alfred C. Jones the Scott's Legacy Premium and Medal for his invention of a friction coupling.

Seven gentlemen were elected members of the Institute by the Board.

The Standing Committee on the Cabinet of Arts and Manufactures reported the election of James H. Cooper as their Chairman, and the adoption of a system of classification for specimens. The other Standing Committees reported their minutes.

The Report of the Resident Secretary on novelties in Science and the Mechanic Arts was then read, as follows:

Secretary's Report.

Cork Springs.—In connexion with new mechanical applications we would call your attention to the use of cork in place of india rubber, as a support for freight cars and like heavy vehicles. One would not be led by any means to predict the efficiency of cork in this connexion, from ordinary impressions of its properties. The cork used for these springs is of the commonest description, harsh, hard, and full of fissures. It is cut into disks of about eight inches diameter, each pierced with a central hole. Previous, however, to cutting, it is soaked in a mixture of molasses and water, which gives it some softness and renders it permanently moist. A number of these cork disks are placed in a cylindrical cast iron box, a flat iron lid or disk is placed over them, and by hydraulic pressure is forced down so as to reduce the thickness to one-half. A bolt is then run through box, corks, and cover at the centre, and a nut being screwed on this, holds all in place, when the press is relieved, and the box of compressed cork, disks, or cork-spring is ready for use.

One of these springs, placed in a testing machine, under a weight of 20,000 lbs., shows an elasticity suggestive of compressed air in a condensing pump. One would expect, from the appearance of the material, that, under heavy pressure, it would be pulverized or split into shreds, especially if this pressure was assisted by violent shocks; but in fact no such action takes place.

A pressure which destroys india rubber, causing it to split up and

lose its elasticity, leaves the cork unimpaired, and, with the machinery in use, it has even been impossible, with any pressure attainable, to injure the cork, even when areas of but one inch were acted upon.

(In connexion with this subject, the President, Mr. Wm. Sellers, remarked, at the conclusion of the Secretary's Report, that he had for some five years, employed a forging machine in which a spring of the form and material above-described was used and subjected to continual and violent shocks, and that its performance had been most thoroughly satisfactory, with no signs of deterioration.)

Howard's breach-loading sporting rifle was then exhibited. Its shape was exceedingly simple and compact, and capacity for rapid manipulation obvious.

Heyl's process for temporary binding or filing of papers, manuscripts, &c., was then explained and illustrated by specimens. In this system, two or three holes are cut with a small circular punch in the "fold" of each signature. At each of these a "binding-tag," (or half circle of paper with a loop of cord incorporated so as to leave only an eye projecting from the middle of its straight side,) is attached by gum already applied, so that the eye projects through the punched hole. Any number of signatures may then be strung together on "laces" run through these eyes, and these laces may be secured to appropriate fastenings in port-folios, between binding-boards, or the like.

Artificial Stone.—Among other valuable works transmitted to the Institute by Mr. James Swaim, now resident in Paris, is a pamphlet on the manufacture of artificial stone or beton, according to the plan devised by M. F. Coignet, accompanied by several large sheets containing drawings of columns, capitols, mouldings, and architectural ornaments, which can be supplied to order. In view of the extensive applications and yet more extensive applicability of this material, all accounts of its use are of value to us. The points of peculiarity about the system mentioned above, are the relative dryness of the materials, their fine division, complete incorporation by trituration, and final compacting by the blows of heavy machinery.

The substances employed are, as with beton generally, sand, stone, hydraulic cement, &c.

In the process as conducted, the material is in some cases, forced into small stationary moulds, by which blocks, mouldings, and the like, of stone are produced; while, in other instances, the material is driven into adjustable moulds arranged on the site of the work to be erected, and these being moved and extended as the construction advances, a monolithic structure is produced, having for many purposes great advantages over any other sort of architecture.

It appears that there have been thus constructed in Paris about sixteen miles of aqueducts and sewers, the foundations of an extensive depot for the Railway "Du Nord," the new prison of the Madelonnettes, and also the entire building for the Municipal Barracks covering an area of 22,000 square feet, and the tower of a church (of Vesinet) 130 feet high. Many cisterns for water, for gas-holders, &c., have also been built in this manner with entire success.

In a former report, Vol. L., page 66, mention was made of many extensive structures, such as dry-docks, break-waters, &c., which had been constructed with similar material.

Astronomy.—Prof. Huggins observes that the small stars constituting the trapezium in the nebula of Orion are very variable in their brilliancy, and suggests that they may be physically connected with this nebula, and since the latter has been proved to be of a gaseous and not stellar constitution, and by consequence to be at no great distance, much may be learned about its nature by a study of these variations.

An extended comparison of the Kew heliographs, which, by the way, are now all taken by Miss Beckly, daughter of the mechanical assistant, it would appear that the absorptive action of the sun's atmosphere upon his light rays, which causes a notable loss of strength in the photographs around the edges of the disk, is affected by the position of the planet Venus through her attractive effect upon the sun and his atmosphere.

Optics.—*Reflectors of Silvered Glass.*—Some improvements have been made in these instruments by Mr. John Browning. The most important are a plan of suspending the small diagonal reflector or prism by three fine wires in place of a single stout arm, and in protecting the mirror from the action of the atmosphere by a cover of plate glass. The cheapness and power of these instruments is drawing much attention to them.

Nichols' Prism, (New Form.)—MM. Hartnack and Prazmowski have exhibited before the French Academy, Nichols' prisms of remarkably large field, and with other advantages, such as avoidance of the loss of light occasioned by reflection from oblique surfaces.

These prisms are described as follows: The natural rhomb of Iceland spar is cut by a plane perpendicular to its axis in place of one passing through that axis, as in the usual form. The cut surfaces are then polished and cemented, in their natural positions, with Canada balsam or linseed oil, their ends being cut off so as to form angles of 79° or of 73·5° with the cut first mentioned, according to the cement used, as above stated.

Glass Mirrors plated with Platinum.—In a late number of the *Bulletin* of the Society for the Encouragement of National Industry, (French,) we find an extensive report on a new process for plating mirrors, which we briefly noticed some time since. The process has so many original features, and so many possible applications that an abstract of its chief points will be valuable.

One hundred grains of pure platinum are dissolved in aqua regia, and the chloride formed is evaporated to dryness, with care to avoid decomposition. This is pulverized, and to it is added essence of lavender, at first slowly, but when the temperature begins to rise, rapidly, until 1400 grains have been so used. The solution is allowed to settle for some days, is decanted and again allowed to settle. There are then taken 25 grains of litharge and 25 grains of borate of lead. These are thoroughly ground with 8 or 10 grains of essence of laven-

der, and then mixed with the platinum solution just described, which is then spread in repeated coatings with a brush upon the glass previously polished and well cleaned.

The varnish, as we may call it, is then allowed to dry spontaneously, and when quite dry the plates are set vertically in a muffle and heated to the required temperature for the decomposition of the mixture and the fusion of the flux.

Some of the advantages of this process are as follows: Any sort of glass may be employed, no matter what its color or irregularity of structure, provided one surface only is level and polished. The reflecting surface being on the outside, no confusion is made, as by the reflection in the common mirror from two surfaces.

The metallic particles are protected by the flux from all atmospheric influences. The reflecting surface is made up of metallic particles, and thus, though the mirror is an excellent reflector, it is also transparent in some degree.

Electro-magnets with uncovered Wires.—In another number of the publication above mentioned, we find in full Du Moncel's report upon the use of uncovered wires for electro-magnets. From this it appears that when currents of low intensity but large quantity are employed, such magnets have a notable advantage over others wound in the usual manner. They may thus be employed with good result for clocks, bells, and telegraphic instruments operated by local batteries. Where intense currents are employed and the resistance is great, as in long coils of fine wire, the uncovered coils are inferior in efficiency to those made with insulated wire. The uncovered coils have also the great advantage of freedom from the extra-current which, producing a bright spark at each rupture of contact, is a fruitful source of destruction to the commutators, interrupters, &c., so much employed in most magnetic machines.

Substitute for Nitric Acid in the Bunsen Battery.—Attention was called some months since to the advantages offered by a mixture of bichromate of potash, water, and sulphuric acid in the Bunsen battery. Extended experience has led us to modify the recipe then given, while it has greatly raised our opinion of the value of this material. We now find the best proportions to be as follows: To one gallon of water, one pound of *pulverized* bichromate of potash and 2½ lbs. of commercial oil of vitriol. With this mixture we have obtained effects fully equal to those produced by nitric acid, with a gain from absence of fume, only to be appreciated by those familiar with the working of large batteries.

Iron Battery with same.—An extensive series of experiments has convinced us that this mixture is not applicable in this case. The fluid, as in the above recipe, gave an excellent current for a few minutes, after which the iron began to be attacked and the current fell off. A solution with no excess of sulphuric acid was then tried, but this gave a current too feeble to be of value, and, increasing the proportion of acid, it was found that a good current was only obtained when the liquid was capable of attacking and did soon attack the iron.

It would seem that as soon as sesquioxide of chromium is formed by the action of the battery, it makes, with the iron, a local circuit in which the latter is the positive or dissolved element. Going to the other extreme and using concentrated oil of vitriol, in which bichromate of potash was dissolved, an equally unfortunate result was encountered, the battery giving no force until such dilution as caused an attack of the iron was reached.

Chemistry.—*Etching on glass with a dead surface* may be effected with the following fluid mixture, which may be applied more certainly and conveniently than the gaseous hydrofluoric acid which has heretofore been the only means for obtaining this effect. Water, 1000 grains; crystallized fluorhydrate of fluoride of potassium, 250 grains; sulphate of potassium, 140 grains; muriatic acid, 250 grains.

By Solution in an equal weight of water, sulpho-cyanide of ammonium will lower the temperature from 60° to 10° Fahr.

A Delicate test for Iodine and Bromine is said to present itself in petroleum, to which these substances in very minute quantities communicate a distinct tint.

Good Crucibles for Melting Steel, rendering it less liable to blister, may be made from magnesia consolidated by pressure, according to M. Caron; and M. Balard, for like reasons, suggests the use of magnesia bricks in puddling furnaces.

A Process for the Manufacture of Sulphuric Acid without leaden chambers is described at some length in the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale.* Its prominent feature is the use of numerous earthenware columns filled with fragments of coke, through which the sulphurous fumes are caused to pass while nitric solutions are dripping down, being constantly returned to the summit by pumps. The plan in its general features is by no means new. Heretofore such arrangements have not proved successful on account of the great amount of nitric acid lost as compared with that expended in the leaden chambers.

From a long course of experiments conducted some years back, we have reason for believing that such a plan as the above is rendered much more efficient if a very tall column is employed, the lower part being warmed by a steam jacket, and the upper part cooled by any convenient means.

Cattle Plague and Carbolic Acid.—In the recommendations drawn up by the Royal Commissioners on the subject of the cattle plague, the greatest stress is laid upon the use of carbolic or cresylic acid, which, mingled with water, is to be used for washing, sprinkling, and sponging. Next to this is ranked sulphurous acid, obtained by burning sulphur on the premises, and, last of all, chloride of lime, which, in this respect, seems to have almost lost its character as a disinfectant.

After the conclusion of the Secretary's Report, Mr. Lippman explained his plan for the use of oblique-headed spikes and nails.

The meeting was then, on motion, adjourned.

HENRY MORTON, *Secretary.*